
Status and Trends of Selected Living Resources in the Galveston Bay System

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VI. MARSH BENTHOS

Roger Zimmerman

INTRODUCTION

Coastal wetlands are highly productive ecological systems on the interface between the land and sea. They are vital as areas of nutrient cycling, carbon flux, and sediment binding, and are habitat for many types of plants and animals. One important attribute is their value as nurseries to estuarine-dependent fishery species. At least 96 percent of commercial and 70 percent of recreational fish taken in the southeast region of the U.S. are estuarine-dependent at some point in their life cycle. In the Galveston Estuary, the principal fishery species that depend on estuarine wetlands are brown shrimp, white shrimp, blue crab, red drum, spotted sea trout, southern flounder and Gulf menhaden. Tidal wetlands in the Galveston Estuary, like those throughout the northwestern Gulf of Mexico, are mainly brackish and saltwater marshes.

Through recent investigations, we know that utilization of marshes may influence the productivity of fisheries. In the past, it was thought that fishery species used marsh creeks, but did not directly use marsh surfaces as nurseries (Weinstein 1979). Early indications of direct utilization came from evidence that marsh infauna, as prey, were affected by aquatic predators (Bell and Coull 1978). It was also shown that offshore yields of some fishery species, such as brown shrimp, could be related to the amount of marsh area inshore (Turner 1977). But it was not until drop trap and flume net sampling methods (Zimmerman et al. 1984; McIvor and Odum 1986) could quantify numbers of predators on marsh surfaces, that the degree of external exploitation became known. The recent studies revealed that estuarine nekton (especially the juveniles of fishery species) invade tidal marsh surfaces in large numbers (Zimmerman et al. 1984; Rozas and Odum 1987; McIvor and Odum 1988; Hettler 1989; Mense and Wenner 1989). In the Galveston Estuary, the densities of predatory consumers were significantly higher in marshes than in nonvegetated subtidal habitat (Zimmerman et al. 1984). Moreover, those densities of secondary consumers in salt marshes were equivalent to densities found in seagrasses (Thomas et al. 1990; Zimmerman et al. 1990).

Manipulative experiments have demonstrated that attraction to marsh habitat improves both the growth and survival of shrimp and blue crab juveniles (Thomas 1989; Minello and Zimmerman 1991). In field caging experiments, shrimp grew faster in marshes than on bare substrate (Zimmerman 1984b). At the same time, predators were less effective and shrimp survival increased (Minello and Zimmerman 1983). These findings confirm that accessibility and quality of food and cover on marsh surfaces can modify productivity of shrimp and other fishery species.

The most abundant prey (forage animals) on marsh surfaces available to shrimp, crab or fish predators are small infaunal and epifaunal amphipods, tanaidaceans and annelid

worms (Thomas 1976, Kneib 1982, Rader 1984). Importantly, these prey are usually primary consumers and, as such, serve as principal links in food chains and in transferring energy to higher trophic levels. Mechanisms controlling the availability and abundances of these prey may greatly determine the extent of coupling between marsh and open water communities in estuaries.

One result of increasing access to primary consumers in marshes as prey may be greater production in fisheries (Boesch and Turner 1984; Minello and Zimmerman in press). Indirect evidence of this is seen in correlations between annual fluctuations in sea level (which influences the frequency and duration of flooding in marshes) and productivity of fisheries (Childers et al. 1990 and Morris et al. 1990). In addition, higher utilization of marsh surfaces during periods of seasonally high water has been reported for fishery species (1984). Nevertheless, studies of abundance relationships between predators and prey on marsh surfaces are rare.

The National Marine Fisheries Service has been pursuing measurement of predator and prey abundances in marshes of the Galveston Estuary since 1985. System-wide surveys of 6 marsh sites in the estuary were conducted during 1987, 1989 and 1990. Faunal densities from drop trap samples and sediment cores were taken in these surveys. The results of the 1987 survey are reported in Zimmerman et al. (1990). Samples collected in the 1989 and 1990 surveys are still being processed. In addition to the system-wide surveys, a long-term marsh study has been conducted at Galveston Island State Park since 1982. These studies employ drop trap sampling to compare densities of shrimps, crabs and fishes in tidal marsh habitat with densities in subtidal mud bottom (nonvegetated) habitats. In 1985, sediment cores were added to the sampling program at the State Park to measure densities of epifauna and infauna as prey. These sampling efforts are continuing.

The information in this report comes from the NMFS 1987 marsh survey of the Galveston Estuary and from 1985 through 1989 marsh monitoring at Galveston Island State Park. In the latter study, the processing of the monthly data sets is incomplete. A review of the literature confirms that these studies are the only comprehensive surveys of marsh invertebrates in the Galveston Estuary.

MATERIALS AND METHODS

In both NMFS surveys, the infauna were sampled using 10 cm diameter PVC coring tubes, as sampling devices, pushed 15 cm into the sediment. From each core, the upper 5 cm of sediment was removed and washed through a 0.5 mm sieve. Sample material remaining on the screen was placed into self-sealing plastic bags in the field with labels, 5 percent formaldehyde in seawater, and Rose Bengal stain. Samples were processed in the laboratory by sorting, identifying and counting the macroinvertebrate infauna.

Infauna were always sampled in conjunction with drop trap sampling designed to measure densities of predatory decapods and fishes. The core samples were always taken from inside the 2.6 m² area circumscribed by drop samples. The number and distribution of core replicates varied depending upon the study design.

Study Designs

Both studies addressed the differences in faunal densities within and between marshes and open water habitats in the Galveston Estuary. The samples from the marsh surface were taken within 1 m of the outer edge. Open water samples, adjacent to the marsh, were usually subtidal and without vegetation. At some open water sites in the Trinity Delta and Christmas Bay, samples were taken within submerged aquatic vegetation (SAV) habitat. These marsh-associated habitats were sampled within 5 m of the marsh edge.

The 1987 survey compared six marsh locations along the salinity gradient of the Galveston Estuary, that extends from the oligohaline Trinity River delta to polyhaline Christmas Bay (Figure VI.1). In the salinity gradient study, 4 replicates of drop samples and sediment cores were taken per season from each habitat at each location (described in Zimmerman et al. 1990).

The monitoring study at Galveston Island State Park follows seasonal and annual variations of nekton and infauna at one marsh location in the lower system. In this study, 8 replicate cores and drop samples are taken in each habitat type monthly. Two types of core samples are obtained from the marsh surface; one includes sediment and marsh plant material (marsh surface with vegetation) and the other incorporates only the bare substrate between the marsh plants (marsh surface without vegetation). Cores taken from the adjacent subtidal open water at the State Park do not include rooted plant material (no SAV). A description of the location and the drop sampling method are in Zimmerman et al. (1984).

Analyses

Macroinvertebrate benthos taken from sediment cores are analyzed in this report. For the sake of brevity, the term "infauna" is used to include both infauna (those animals in sediments) and epifauna (those animals on the surface of sediments or inhabiting benthic plants). The main tests were for level of differences between means of abundances among habitat types and among sites positioned in different parts of the bay. The analyses were performed using factorial analysis of variances (ANOVAs) and pairwise t-tests. Means of abundances were plotted to show seasonal and annual changes in dominant species and taxonomic groups (annelids, peracarids, mollusks and others) as well as to show differences between habitats.

RESULTS

The Estuary-Wide Survey

Shallow-water infauna were analyzed from six locations in the Galveston Estuary during the spring, summer and fall periods of 1987. Sampling was stratified by habitat type (marsh and associated open water habitats) and position in the system (upper, middle and lower). Sampling locations were the Trinity River delta, Smith Point, Moses Lake, Galveston Island State Park and Christmas Bay (Figure VI.1). The locations were chosen to reflect differences in oligohaline, mesohaline and polyhaline influences on marsh and adjacent shallow-water communities of the system.

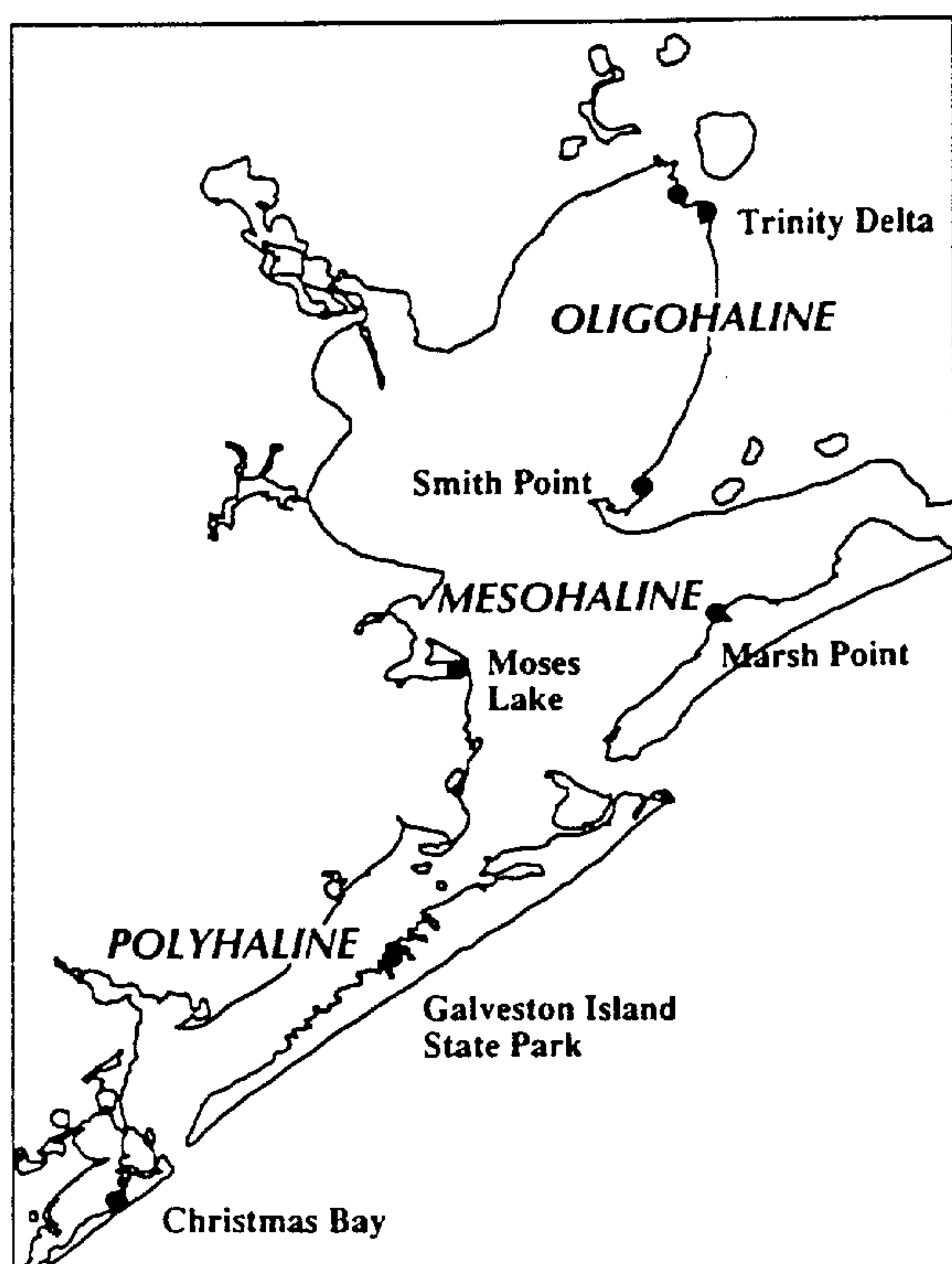


Figure VI.1. Marsh survey sites for macro-invertebrate infauna in the Galveston Estuary during 1987 (from Zimmerman et al. 1990).

The Upper System

Mean salinities at the two marsh sites of the delta ranged between 0 and 10.8 ppt. The overall salinity regime was oligohaline (0.5 to 5 ppt). Spring to mid-summer salinities were generally less than 2 ppt. Fall salinities were highest of the year following the usual seasonal pattern. Marsh plants were bulrushes (*Scirpus* spp.), arrowheads (*Sagittaria* spp.), alligator weed (*Alternanthera philoxeroides*), pickerel weed (*Pontederia cordata*), water hyssop (*Bacopa monnieri*) and switchgrass (*Panicum* sp.). Subtidal plants included quillwort (*Isoetes* sp.), widgeon grass (*Ruppia maritima*) and tapegrass (*Vallisneria americana*). Plant cover was sparse in the winter and spring becoming luxuriant by summer. The winter die-back began in the fall and was the source of large amounts of plant detritus exported downstream annually.

The Middle System

Mean salinities at Smith Point and Moses Lake ranged between 0.8 and 20.5 ppt. The mid-bay was mesohaline overall (6 to 23 ppt), but variation was greater any other part of the system. Spring salinities were 8 to 15 ppt, summer salinities 0.8 to 9 ppt and fall salinities were 20 to 22 ppt. Marshes were mixed stands of smooth cordgrass (*Spartina alterniflora*), marsh hay (*Spartina patens*), black rush (*Juncus roemerianus*) and saltgrass (*Distichlis spicata*). As in the lower system, these marsh plants were perennial. Submerged vegetation did not occur in the middle system.

The Lower System

Mean salinities at Galveston Island State Park and Christmas Bay sites ranged between 22.1 and 33.3 ppt. This lower bay area is normally polyhaline, but summer droughts or tropical storms can create hypersaline or low salinity conditions. Emergent plants are salt marshes comprised of smooth cordgrass (*S. alterniflora*) with lesser amounts glasswort (*Salicornia* spp.) and saltwort (*Batis maritima*). Christmas Bay has some stands of seagrasses including shoal grass (*Halodule wrightii*), widgeon grass (*Ruppia maritima*) and turtle grass (*Thalassia testudinum*) and star grass (*Halophila engelmannii*). Stands of shoal grass and widgeon grass previously observed at the State Park (in the late 1960s and early 1970s) are no longer present.

Macroinvertebrate Abundances and Distributions

Annelid worms (polychaetes and oligochaetes) and peracarid crustaceans (primarily amphipods and tanaidaceans) made up more than 90 percent of macroinvertebrate infaunal abundances at every marsh site in the Galveston Estuary (Table VI.1). Annelids were prevalent in marshes of the upper and lower system and peracarids dominated the middle system marshes. Peracarids were virtually absent from the upper system. Small mollusks comprised less than 3 percent of infaunal abundances at any one marsh site. Large bivalves and gastropods were poorly sampled because of the small size (78.5 cm²) of the coring device.

Table VI.1. Abundances of infauna in sediment cores from marsh sites in the Galveston Estuary: 78.5cm² cores, 8 cores at each site x 3 seasons. From Zimmerman et al. (1990).

Group	Inner Delta	Outer Delta	Smith Point	Moses Lake	State Park	Christmas Bay
	# (%)	# (%)	# (%)	# (%)	# (%)	# (%)
Annelids	5074 (93)	2663 (92)	971 (44)	4800 (30)	2567 (51)	1923 (86)
Peracarids	6 (<1)	16 (<1)	1172 (53)	10835 (68)	2315 (46)	211 (9)
Mollusks	157 (3)	35 (1)	32 (1)	8 (<1)	14 (>1)	46 (2)
All Others	<u>231 (4)</u>	<u>174 (6)</u>	<u>49 (2)</u>	<u>391 (2)</u>	<u>157 (3)</u>	<u>48 (2)</u>
Totals	5468	2888	2224	16034	5053	2228

Seasonal Variations and Habitat Relationships

Seasonal changes in densities of infauna can reflect production potential and relative predation effects among sites. Production potential among sites can be compared using spring densities because predation from shrimp and fish is less in the winter. As the spring and summer progress, predation increases and lower infaunal densities result under predation pressure. Comparison of the fall season densities reflect degree of predation among sites.

For total infauna (Figure VI.2), the Trinity River delta and Christmas Bay marsh sites showed the least amount of seasonal change; whereas Moses Lake, Smith Point and the State Park sites exhibited the greatest change between spring and fall seasons.

Annelids (Figure VI.3) changed least in abundance seasonally among all infauna. The delta sites increased in mean density of annelids between the spring and fall. Moses Lake showed no change, and at Smith Point, the State Park and Christmas Bay annelid densities declined. None of the seasonal changes in annelid densities were statistically significant within sites.

Peracarid densities (Figure VI.4), unlike annelids, varied significantly between seasons within marsh sites and also overall between marsh sites. Peracarids (amphipods, tanaidaceans and isopods) were virtually absent in all seasons from the delta marsh sites. But marshes at Moses Lake, Smith Point and the State Park exhibited especially high densities of peracarids in the spring. These sites demonstrated significant density declines between the spring and fall seasons. The marsh at Christmas Bay did not have notably high spring densities although densities declined too by fall.

Molluscan densities (Figure VI.5) were highest overall in marshes of the delta and the middle bay. Seasonal trends were not evident in mollusk density patterns. The low numbers of mollusks in Galveston Estuary marshes compared to other infauna are notable.

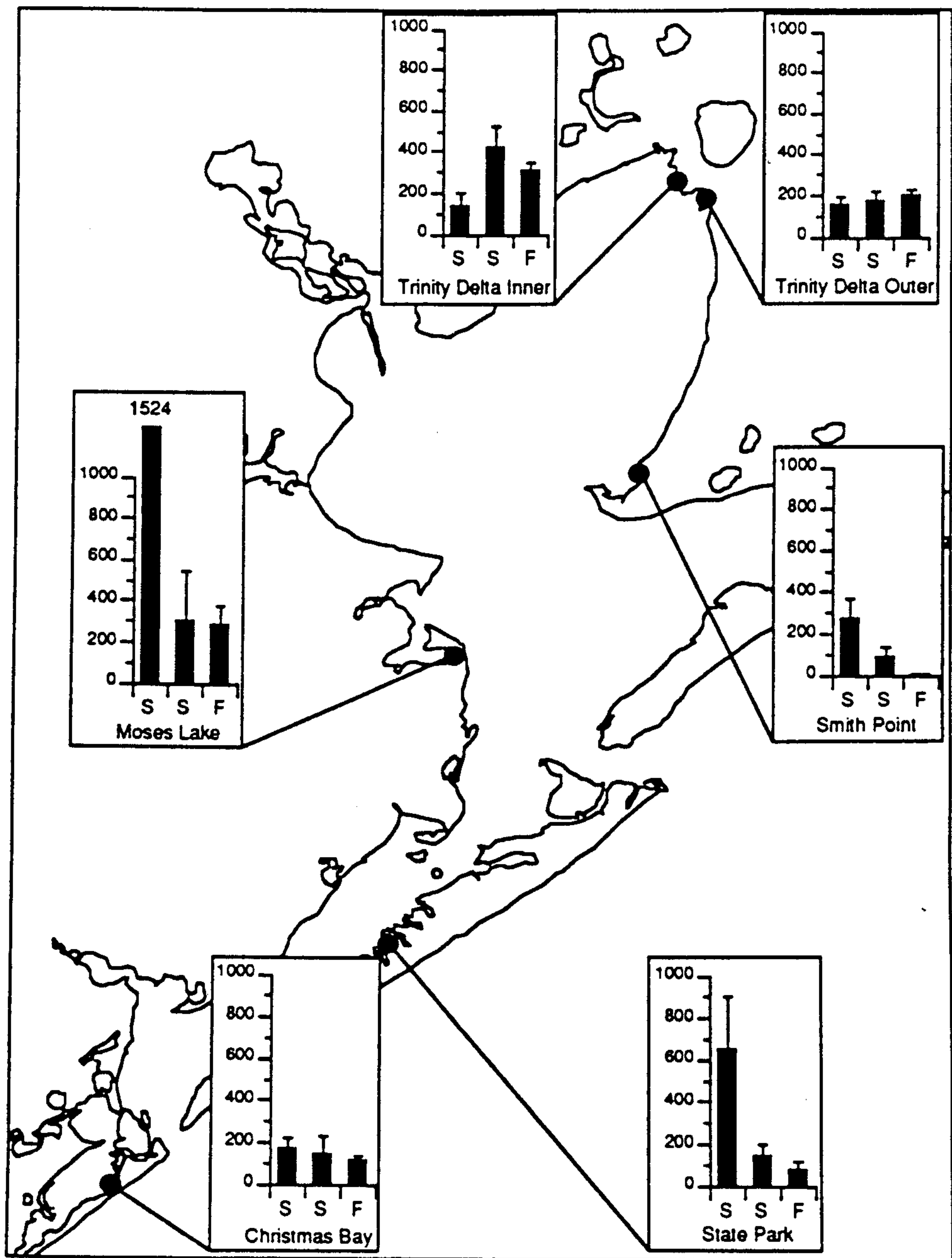


Figure VI.2. Abundances of total infauna and epifauna in sediment cores at marsh sites in the Galveston Estuary: 78 cm² cores, 4 cores each in spring, summer and fall seasons. From Zimmerman et al. (1990).

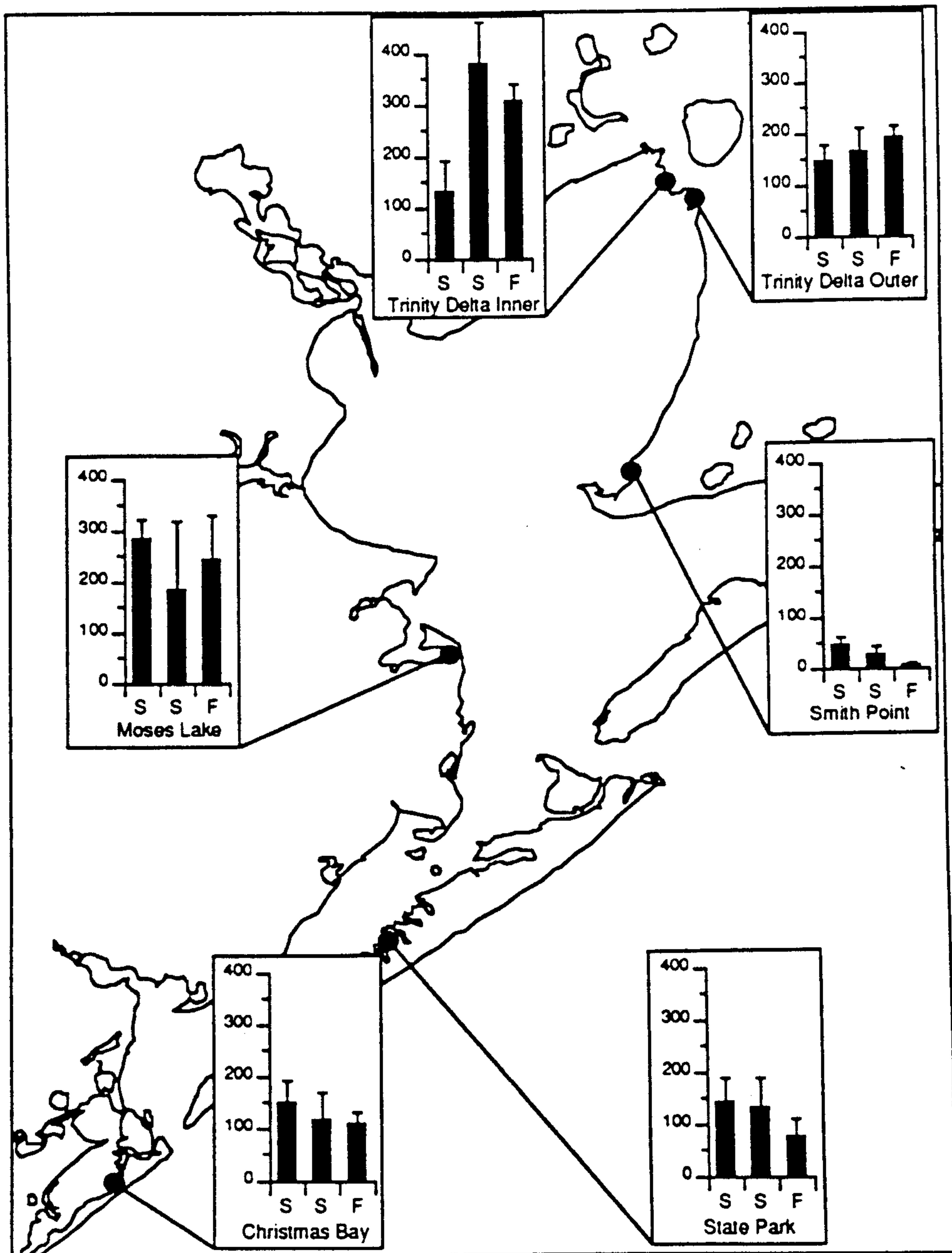


Figure VI.3. Abundances of annelids in sediment cores at marsh sites in the Galveston Estuary: 78 cm² cores, 4 cores each in spring, summer and fall seasons. From Zimmerman et al. (1990).

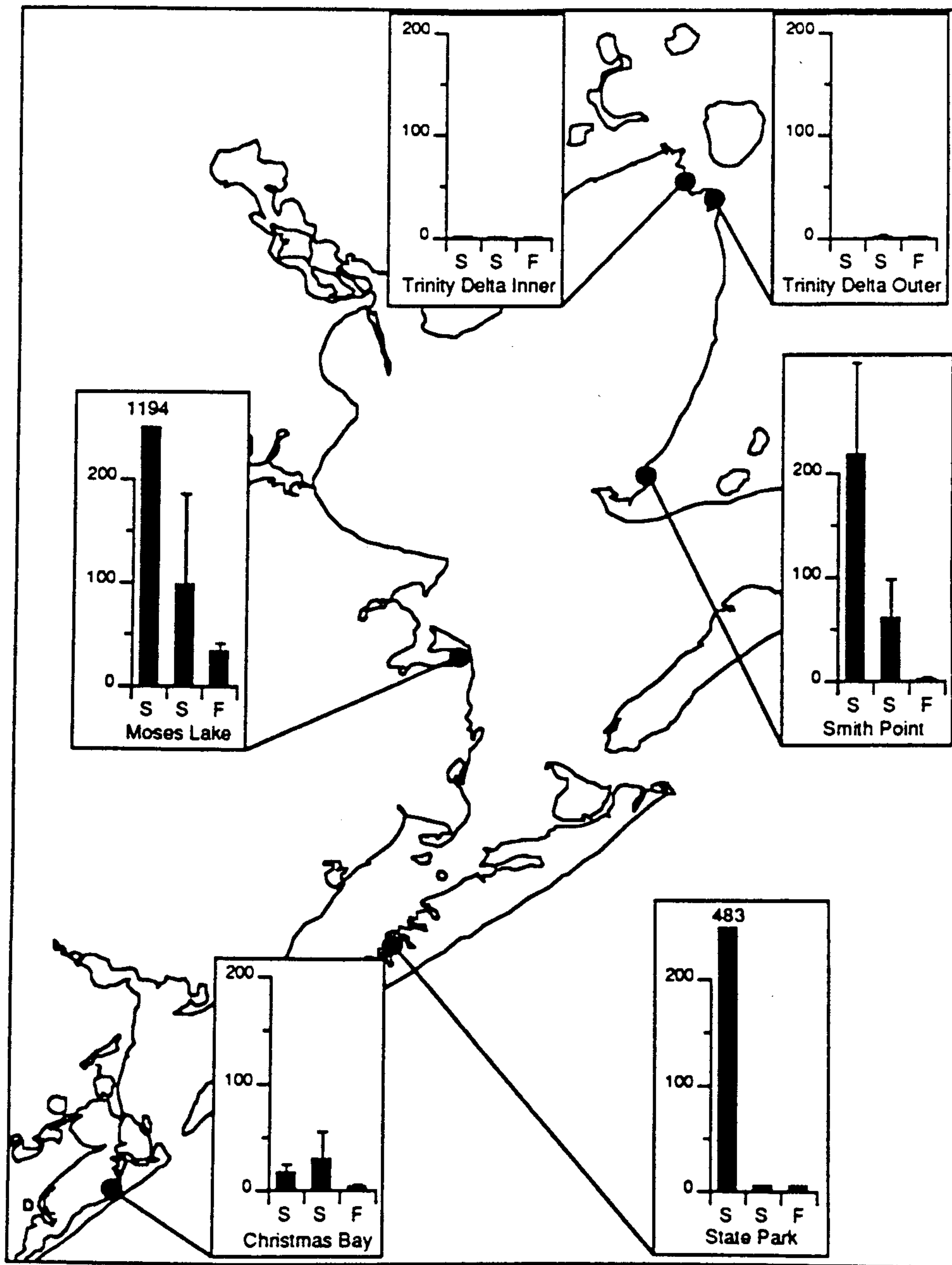


Figure VI.4. Abundances of peracarids in sediment cores at marsh sites in the Galveston Estuary: 78 cm² cores, 4 cores each in spring, summer and fall seasons. From Zimmerman et al. (1990).

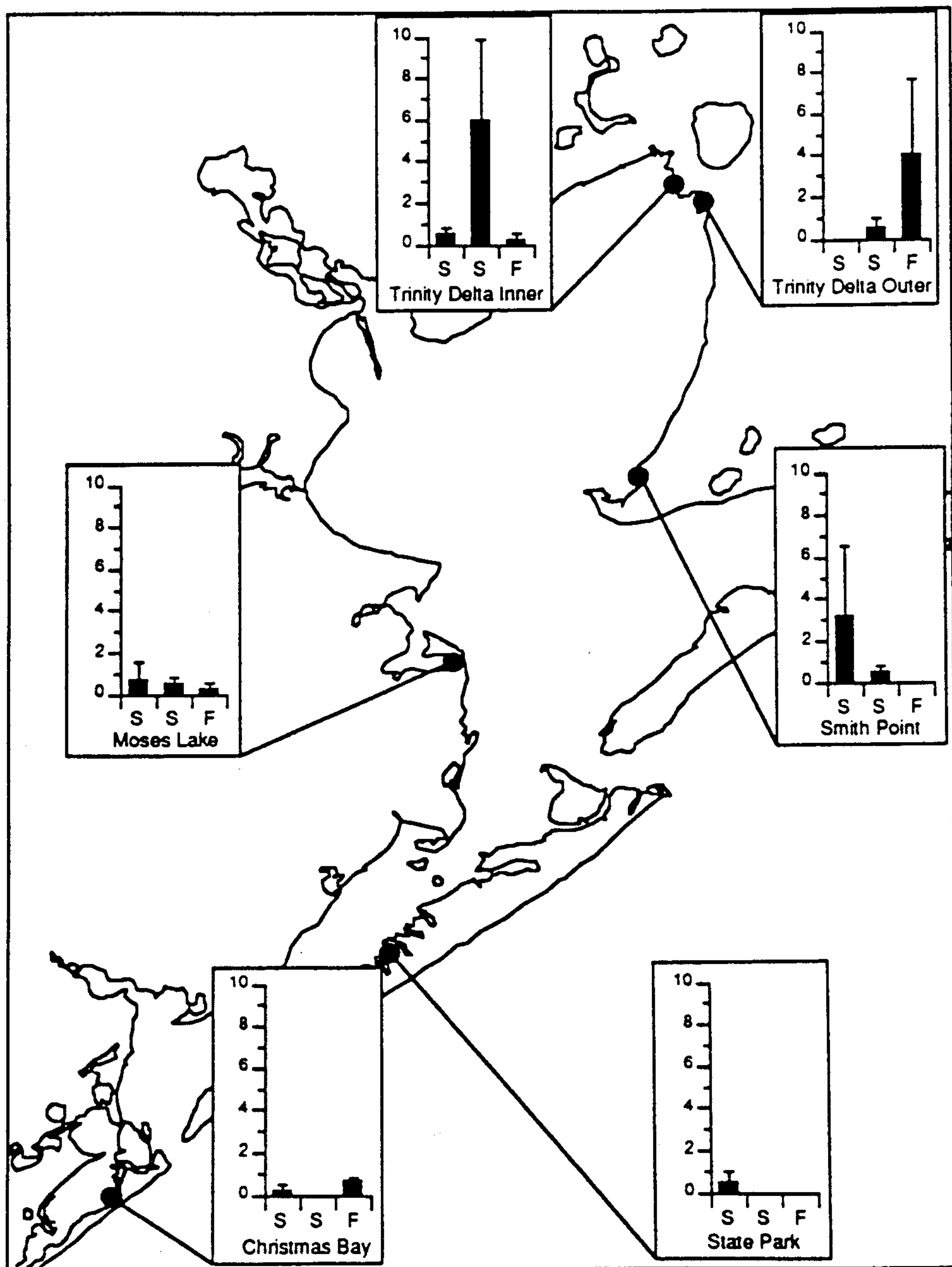


Figure VI.5. Abundances of molluscs in sediment cores at marsh sites in the Galveston Estuary: 78 cm² cores, 4 cores each in spring, summer and fall seasons. From Zimmerman et al. (1990).

Miscellaneous taxa (Figure VI.6) from marsh sediments in the Galveston Estuary were mostly insect larvae, nemerteans, turbellarians, ascideans and large nematodes. Highest densities of these taxa varied among marsh sites and seasons. Highest densities overall occurred at the inner delta marsh in the summer and at Moses Lake and the State Park during the spring. Christmas Bay and Smith Point densities were low in all seasons. Declining spring to fall densities were evident at Moses Lake and the State Park.

The State Park Long-Term Survey

Infauna from the three types of cores, representing three habitats, were sampled monthly for abundance at the Galveston Island State Park beginning in 1985. The sampled habitats were: a) marsh substrate with plants, b) marsh substrate without plants and c) subtidal substrate without plants.

Dominant Infauna

Annelids and peracarids, as in other marshes of the Galveston Estuary, were the predominant infauna in all three of the State Park habitats. Among annelids (Table VI.2), the most consistently abundant species were Streblospio benedicti, Capitella capitata, an unidentified oligochaete, Mediomastus californiensis, Euchone spp., Heteromastus filiformis, Neries succinea, Polydora ligni, Mediomastus ambiseta, Hobsonia florida and Tharyx setigera. Among peracarids (Table VI.3), Hargeria rapax, Corophium spp., Gammarus mucronatus, Ampelisca abdita, Melita nitida, Grandidierella bonneroides, Edotea montosa, Orchestia costaricana were most abundant year to year.

Molluscan abundances (Table VI.4) were dominated by bivalves including Mulinia lateralis, Amygdalum papyrium, a species of an unidentified genus, Tagelus sp., Tellina spp. and Brachiodontes exustus. The oyster, Crassostrea virginica, was notable for its absence. Gastropoda were rare.

Seasonal, Annual and Habitat Trends

The seasonal patterns of infaunal abundances are depicted in monthly means. The annual patterns and trends of overall infauna (Figure VI.7), annelids (Figure VI.8), peracarids (Figure VI.9), mollusks (Figure VI.10) and miscellaneous taxa (Figure VI.11) are available for the years 1985, 1986, 1987 and 1988. The most complete monthly data are from March 1985 through May 1986. In the remaining years, monthly samples were taken but not all of the data has been processed. As a result, representation of annual peaks and lows is fragmentary.

In general, the winter and early spring densities of infauna (cold months) were elevated and late spring through fall densities (warm months) were low. Samples of marsh substrate with plant material always had more infauna than samples of bare subtidal substrate. Samples of marsh substrate without plant material had infaunal densities equivalent to marsh with plants during the winter and early spring (high density months),

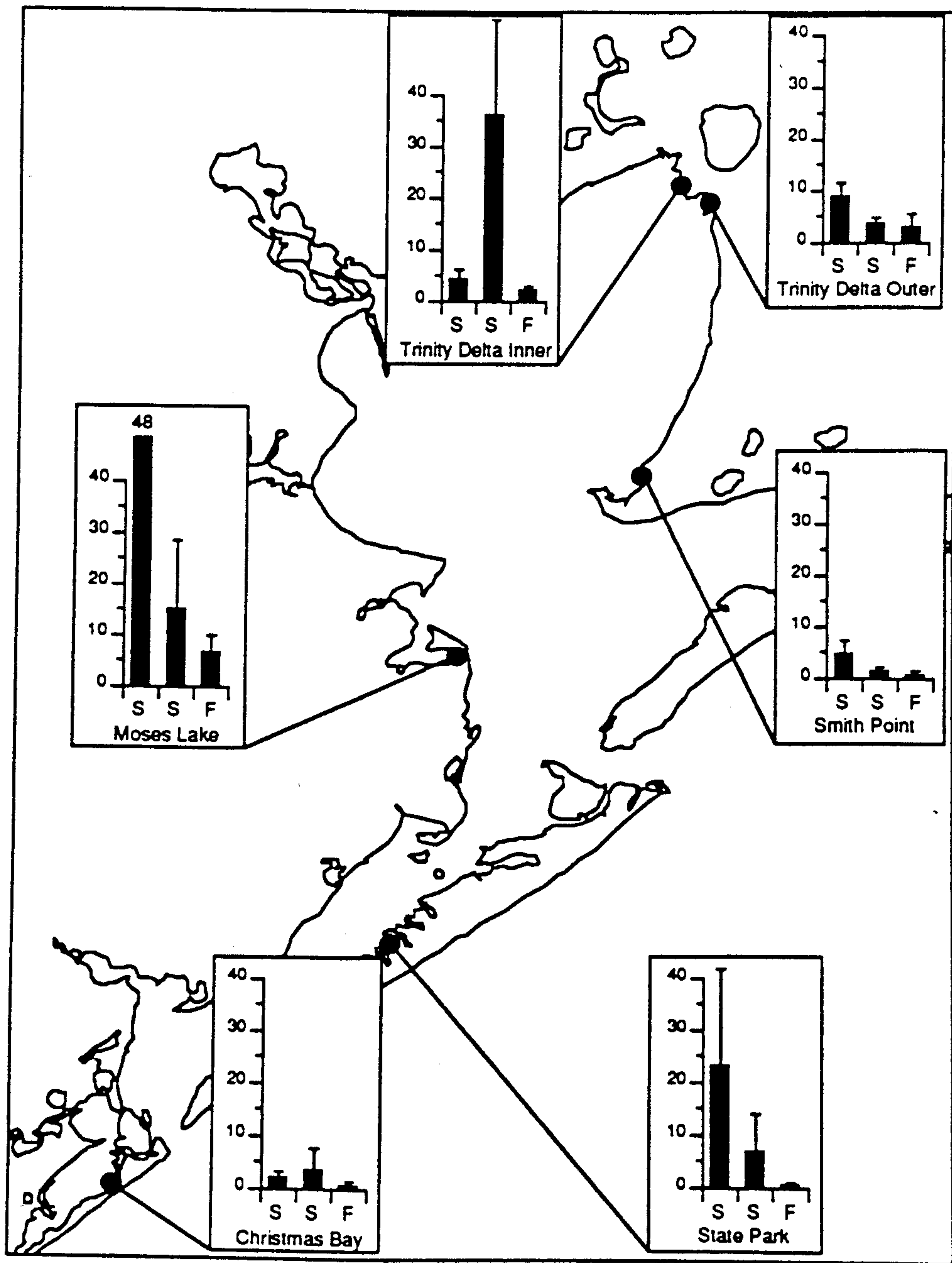


Figure VI.6. Abundances of miscellaneous infauna and epifauna in sediment cores at marsh sites in the Galveston Estuary: 78 cm² cores, 4 cores each in spring, summer and fall seasons. From Zimmerman et al. (1990).

Table VI.2. Annual variation in percent abundance of annelid worms among infauna of three types of habitats associated with a salt marsh on Galveston Island, Texas.

MARSH SUBSTRATE WITH PLANTS	1985		1986		1987		1988	
	%ANNE	%TOTAL	%ANNE	%TOTAL	%ANNE	%TOTAL	%ANNE	%TOTAL

ABUNDANCE RANK AMONG 66 SPECIES:								
1. Streblospio benedicti	59.97	25.31	59.26	27.33	45.07	12.35	41.47	14.55
2. Oligochaete, unidentified	19.98	8.43	9.58	4.42	20.05	5.50	18.56	6.51
3. Capitella capitata	12.12	5.12	10.18	4.69	18.71	5.13	16.31	5.72
4. Mediomastus spp.	1.95	0.82	10.04	4.63	1.47	0.40	6.40	2.25
5. Mediomastus californiensis	2.22	0.94	5.26	2.43	7.12	1.95	5.25	1.84
6. Nereis (Neanthes) succinea	0.67	0.28	0.48	0.22	0.98	0.27	2.15	0.75
7. Polydora ligni	0.45	0.19	0.37	0.17	0.33	0.09	2.35	0.82
8. Heteromastus filiformis	0.22	0.09	0.21	0.10	0.16	0.04	2.90	1.02
9. Hobsonia gunneri	0.37	0.16	0.55	0.25	0.56	0.15	0.15	0.05
10. Melinna maculata	0.29	0.12	0.62	0.29	0.29	0.08	0.55	0.19
11. Eumida sanguinea	0.04	0.02	0.02	0.01	1.63	0.45	0.00	0.00
12. Lysidice ninetta	0.12	0.05	0.21	0.10	0.72	0.20	0.30	0.11
13. Nereis falsa	0.00	0.00	0.09	0.04	0.82	0.22	0.10	0.04
14. Laeonereis culveri	0.20	0.08	0.16	0.07	0.20	0.05	0.30	0.11
15. Tharyx setigera	0.04	0.02	0.57	0.26	0.00	0.00	0.00	0.00

MARSH SUBSTRATE WITHOUT PLANTS	1985		1986		1987		1988	
	%ANNE	%TOTAL	%ANNE	%TOTAL	%ANNE	%TOTAL	%ANNE	%TOTAL

ABUNDANCE RANK AMONG 54 SPECIES:								
1. Streblospio benedicti	75.49	32.65	77.14	48.04	67.75	30.91	77.51	53.22
2. Capitella capitata	11.36	4.91	8.45	5.26	17.70	8.08	9.56	6.57
3. Oligochaete, unidentified	6.97	3.02	6.63	4.13	7.08	3.23	5.69	3.91
4. Mediomastus californiensis	1.72	0.75	0.89	0.55	2.78	1.27	1.79	1.23
5. Mediomastus spp.	0.67	0.29	3.57	2.23	0.47	0.22	0.16	0.11
6. Hobsonia gunneri	0.94	0.41	0.71	0.44	0.95	0.43	0.26	0.18
7. Heteromastus filiformis	0.19	0.08	0.23	0.14	0.38	0.17	1.79	1.23
8. Polydora ligni	0.90	0.39	0.20	0.13	0.35	0.16	1.06	0.72
9. Laeonereis culveri	0.19	0.08	0.39	0.24	0.09	0.04	0.26	0.18
10. Nereis (Neanthes) succinea	0.04	0.02	0.23	0.14	0.35	0.16	0.29	0.20
11. Melinna maculata	0.49	0.21	0.18	0.11	0.22	0.10	0.16	0.11
12. Tharyx setigera	0.15	0.06	0.66	0.41	0.00	0.00	0.00	0.00
13. Stenonereis martini	0.04	0.02	0.00	0.00	0.13	0.06	0.42	0.29
14. Lysidice ninetta	0.00	0.00	0.09	0.06	0.25	0.12	0.10	0.07
15. Chaetozone cf. sp. A	0.00	0.00	0.00	0.00	0.41	0.19	0.03	0.02

SUBTIDAL NONVEGETATED SUBSTRATE	1985		1986		1987		1988	
	%ANNE	%TOTAL	%ANNE	%TOTAL	%ANNE	%TOTAL	%ANNE	%TOTAL

ABUNDANCE RANK AMONG 65 SPECIES:								
1. Streblospio benedicti	75.50	38.28	67.45	41.25	57.95	32.43	71.84	46.59
2. Capitella capitata	3.13	1.59	6.08	3.72	16.70	9.35	4.22	2.73
3. Oligochaete, unidentid.	4.46	2.26	6.76	4.14	2.92	1.63	4.58	2.97
4. Mediomastus spp.	3.32	1.69	2.16	1.32	1.41	0.79	4.37	2.84
5. Mediomastus californiensis	0.76	0.39	0.78	0.48	4.73	2.65	4.27	2.77
6. Heteromastus filiformis	0.28	0.14	0.78	0.48	3.42	1.91	3.75	2.43
7. Tharyx setigera	3.42	1.73	4.51	2.76	1.61	0.90	0.00	0.00
8. Hobsonia gunneri	1.23	0.63	2.35	1.44	1.81	1.01	0.62	0.41
9. Mediomastus ambiseta	2.56	1.30	0.20	0.12	2.11	1.18	1.09	0.71
10. Scoloplos fragilis	0.66	0.34	1.57	0.96	1.41	0.79	0.57	0.37
11. Polydora ligni	1.14	0.58	0.88	0.54	0.40	0.23	0.78	0.51
12. Melinna maculata	0.28	0.14	1.27	0.78	1.21	0.68	0.26	0.17
13. Laeonereis culveri	0.85	0.43	0.88	0.54	0.10	0.06	0.62	0.41
14. Aricidea (Acmira) philbinae	0.00	0.00	0.10	0.06	0.40	0.23	0.57	0.37
15. Chaetozone cf. sp. A	0.00	0.00	0.00	0.00	0.50	0.28	0.68	0.44

Table VI.3. Annual variation in percent abundance of peracarid crustaceans among infauna of three types of habitats associated with a salt marsh on Galveston Island, Texas.

MARSH SUBSTRATE WITH PLANTS	1985		1986		1987		1988	
	%PERA	%TOTAL	%PERA	%TOTAL	%PERA	%TOTAL	%PERA	%TOTAL

ABUNDANCE RANK AMONG 20 SPECIES:								
1. Hargeria rapax	51.47	28.81	51.77	27.02	43.42	31.23	26.79	17.08
2. Corophium spp.	40.67	22.76	38.29	19.99	46.17	33.21	44.55	28.40
3. Gammarus mucronatus	5.84	3.27	6.86	3.58	7.65	5.50	5.89	3.76
4. Melita cf. nitida	0.21	0.12	0.00	0.00	0.00	0.00	9.86	6.28
5. Grandidierella bonneroides	0.27	0.15	0.22	0.12	1.07	0.77	6.77	4.32
6. Orchestia cf. costaricana	0.30	0.17	0.00	0.00	0.39	0.28	4.27	2.72
7. Cymadusa compta	0.00	0.00	0.00	0.00	0.49	0.35	0.47	0.30
8. Ampelisca abdita	0.13	0.07	0.55	0.29	0.10	0.07	0.25	0.16
9. Edotea montosa	0.06	0.03	0.49	0.25	0.20	0.14	0.06	0.04
10. Elasmopus cf. levis	0.00	0.00	0.59	0.31	0.00	0.00	0.06	0.04

MARSH SUBSTRATE WITHOUT PLANTS	1985		1986		1987		1988	
	%PERA	%TOTAL	%PERA	%TOTAL	%PERA	%TOTAL	%PERA	%TOTAL

ABUNDANCE RANK AMONG 12 SPECIES:								
1. Hargeria rapax	66.67	37.03	75.06	27.73	65.34	35.29	71.47	21.68
2. Corophium sp.	30.82	17.12	23.10	8.54	25.69	13.88	24.04	7.29
3. Gammarus mucronatus	0.67	0.37	0.31	0.11	4.86	2.63	0.36	0.11
4. Grandidierella bonneroides	0.44	0.24	0.12	0.04	2.11	1.14	0.65	0.20
5. Ampelisca abdita	0.44	0.24	1.07	0.40	1.23	0.66	0.36	0.11
6. Edotea montosa	0.12	0.06	0.04	0.01	0.21	0.12	0.29	0.09
7. Melita nitida	0.00	0.00	0.04	0.01	0.00	0.00	0.72	0.22
8. Cymadusa compta	0.03	0.02	0.00	0.00	0.24	0.13	0.00	0.00
9. Ampithoe sp.	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00
10. Orchestia sp.	0.00	0.00	0.00	0.00	0.05	0.03	0.00	0.00

SUBTIDAL NONVEGETATED SUBSTRATE	1985		1986		1987		1988	
	%PERA	%TOTAL	%PERA	%TOTAL	%PERA	%TOTAL	%PERA	%TOTAL

ABUNDANCE RANK AMONG 11 SPECIES:								
1. Ampelisca abdita	44.70	20.90	71.38	24.52	60.05	24.89	57.04	19.01
2. Corophium spp.	28.42	13.29	8.55	2.94	4.08	1.69	23.00	7.66
3. Hargeria rapax	23.17	10.83	13.09	4.50	10.60	4.39	13.78	4.59
4. Gammarus mucronatus	0.10	0.05	0.52	0.18	18.07	7.49	0.81	0.27
5. Edotea montosa	0.51	0.24	1.40	0.48	2.04	0.84	1.52	0.51
6. Grandidierella bonneroides	1.03	0.48	0.70	0.24	1.90	0.79	1.42	0.47
7. Listriella sp.	0.00	0.00	0.00	0.00	0.27	0.11	0.10	0.03
8. Amphipoda, unidentified	0.10	0.05	0.35	0.12	0.00	0.00	0.00	0.00
9. Caprella cf. equilibria	0.00	0.00	0.35	0.12	0.00	0.00	0.00	0.00
10. Listriella cf. clymenellae	0.00	0.00	0.17	0.06	0.00	0.00	0.00	0.00

Table VI.4. Annual variation in percent abundance of mollusks among infauna of three types of habitats associated with a salt marsh on Galveston Island, Texas.

MARSH SUBSTRATE WITH PLANTS	1985		1986		1987		1988	
	%MOLL	%TOTAL	%MOLL	%TOTAL	%MOLL	%TOTAL	%MOLL	%TOTAL

ABUNDANCE RANK AMONG 11 SPECIES:								
1. Amygdalum papyrium	41.94	0.11	14.29	0.04	38.89	0.06	57.14	0.28
2. Unidentified bivalve	16.13	0.04	39.29	0.12	5.56	0.01	7.14	0.04
3. Unidentified gastropod	3.23	0.01	0.00	0.00	5.56	0.01	35.71	0.18
4. Tellina spp.	16.13	0.04	10.71	0.03	16.67	0.03	0.00	0.00
5. Brachidontes exustus	16.13	0.04	7.14	0.02	11.11	0.02	0.00	0.00
6. Unidentified cerithidae	3.23	0.01	10.71	0.03	0.00	0.00	0.00	0.00
7. Sphenia antillensis	0.00	0.00	10.71	0.03	0.00	0.00	0.00	0.00
8. Mulinia lateralis	0.00	0.00	0.00	0.00	11.11	0.02	0.00	0.00
9. Mysella planulata	3.23	0.01	3.57	0.01	0.00	0.00	0.00	0.00
10. Tagelus sp.	0.00	0.00	0.00	0.00	11.11	0.02	0.00	0.00
11. S8975	0.00	0.00	3.57	0.01	0.00	0.00	0.00	0.00

MARSH SUBSTRATE WITHOUT PLANTS	1985		1986		1987		1988	
	%MOLL	%TOTAL	%MOLL	%TOTAL	%MOLL	%TOTAL	%MOLL	%TOTAL

ABUNDANCE RANK AMONG 14 SPECIES:								
1. Unidentified bivalve	50.00	0.10	75.00	0.17	0.00	0.00	0.00	0.00
2. Tagelus sp.	0.00	0.00	0.00	0.00	23.08	0.04	50.00	0.15
3. Amygdalum papyrium	25.00	0.05	6.25	0.01	15.38	0.03	0.00	0.00
4. Mysella planulata	0.00	0.00	6.25	0.01	15.38	0.03	14.29	0.04
5. Unidentified gastropod	0.00	0.00	0.00	0.00	23.08	0.04	0.00	0.00
6. Semele proficua	16.67	0.03	6.25	0.01	0.00	0.00	0.00	0.00
7. Acteocina canaliculata	0.00	0.00	0.00	0.00	15.38	0.03	0.00	0.00
8. Diastoma varium	0.00	0.00	0.00	0.00	0.00	0.00	14.29	0.04
9. Brachidontes exustus	8.33	0.02	0.00	0.00	0.00	0.00	0.00	0.00
10. Cerithidea pliculosa	0.00	0.00	0.00	0.00	0.00	0.00	7.14	0.02
11. Eulimastoma sp.	0.00	0.00	0.00	0.00	0.00	0.00	7.14	0.02
12. Mulinia lateralis	0.00	0.00	0.00	0.00	7.69	0.01	0.00	0.00
13. Tellina spp.	0.00	0.00	6.25	0.01	0.00	0.00	0.00	0.00
14. Unknown mollusk	0.00	0.00	0.00	0.00	0.00	0.00	7.14	0.02

SUBTIDAL NONVEGETATED SUBSTRATE	1985		1986		1987		1988	
	%MOLL	%TOTAL	%MOLL	%TOTAL	%MOLL	%TOTAL	%MOLL	%TOTAL

ABUNDANCE RANK AMONG 15 SPECIES:								
1. Mulinia lateralis	0.00	0.00	13.79	0.24	63.89	1.30	17.39	0.14
2. Unidentified bivalve	80.00	0.58	17.24	0.30	0.00	0.00	13.04	0.10
3. Tagelus sp.	0.00	0.00	0.00	0.00	16.67	0.34	13.04	0.10
4. Acteocina canaliculata	0.00	0.00	0.00	0.00	8.33	0.17	13.04	0.10
5. Tellina spp.	0.00	0.00	20.69	0.36	0.00	0.00	8.70	0.07
6. Unidentified gastropod	0.00	0.00	6.90	0.12	2.78	0.06	13.04	0.10
7. Mysella planulata	0.00	0.00	17.24	0.30	0.00	0.00	4.35	0.03
8. Amygdalum papyrium	0.00	0.00	0.00	0.00	5.56	0.11	8.70	0.07
9. Sphenia antillensis	0.00	0.00	13.79	0.24	0.00	0.00	0.00	0.00
10. Unidentified cerithidae	0.00	0.00	10.34	0.18	0.00	0.00	0.00	0.00
11. Enis minor	0.00	0.00	0.00	0.00	2.78	0.06	0.00	0.00
12. Rictaxis punctostriatus	0.00	0.00	0.00	0.00	0.00	0.00	8.70	0.07
13. Unidentified Gastropod larva	6.67	0.05	0.00	0.00	0.00	0.00	0.00	0.00
14. Semele proficua	6.67	0.05	0.00	0.00	0.00	0.00	0.00	0.00
15. Unknown mollusk	6.67	0.05	0.00	0.00	0.00	0.00	0.00	0.00

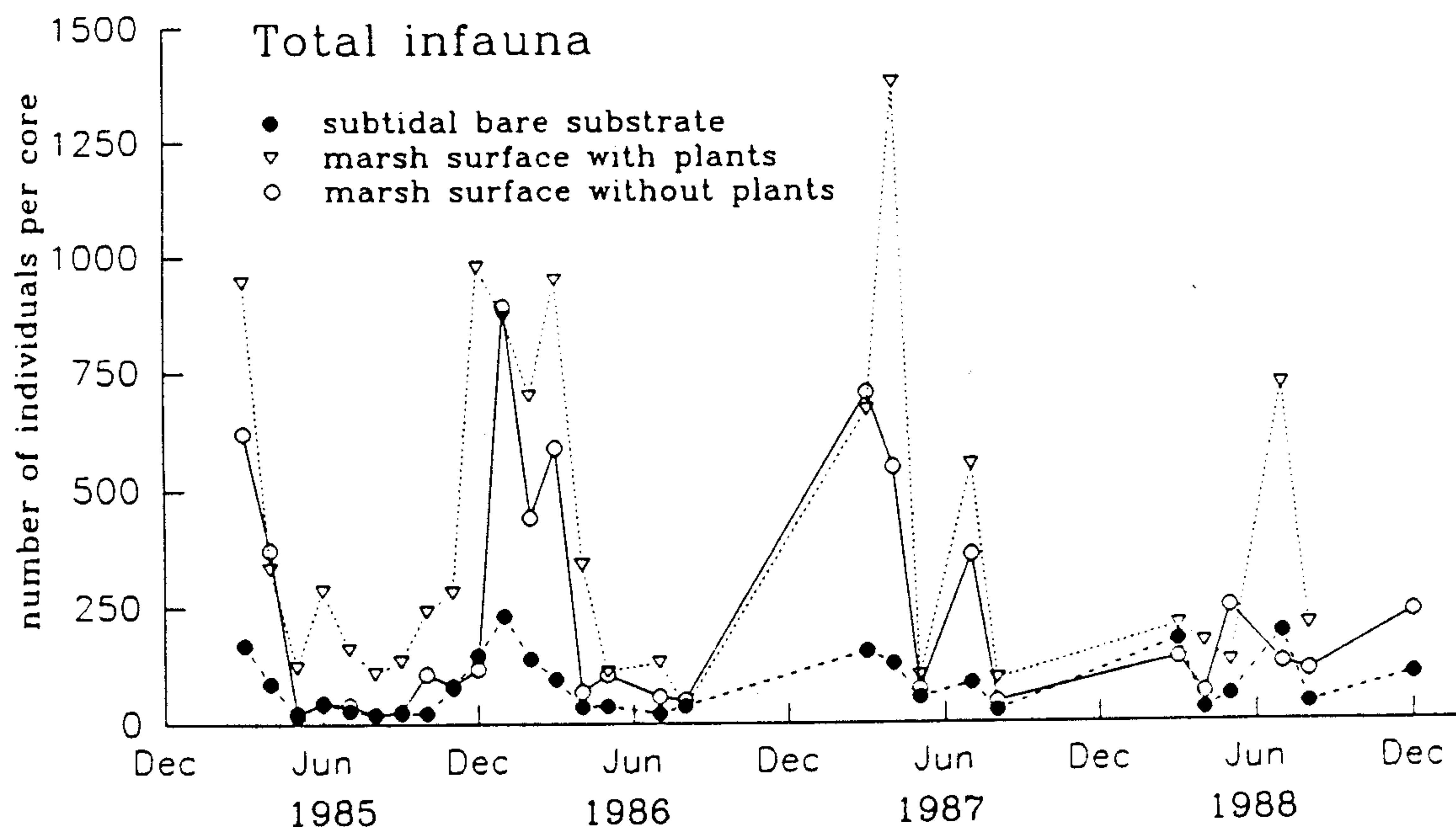


Figure VI.7. Mean abundances of infauna in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

but not during the late spring through fall (low density months). In low density months, infaunal abundances were indistinguishable between marsh substrate without plants and subtidal bare substrate.

Annelid Worms

Annelids dominated the infaunal abundances in most months, and the overall seasonal pattern reflected changes in their densities (Figure VI.8). Likewise, the most abundant annelid taxa, Streblospio benedicti (Figure VI.12), oligochaetes (Figure VI.13), and Capitella capitata (Figure VI.14), comprising 76 to 92 percent of all annelids annually (Table VI.2), dominated the overall pattern for annelids.

Deviation from patterns established by dominant annelids were evident in lesser abundant species. Mediomastus spp. (Figure VI.15) were not always abundant in cold season months and Mediomastus californiensis (Figure VI.16) mainly associated with plants. Mediomastus ambiseta (Figure VI.17), unlike other congeners, were more abundant subtidally than on the marsh surface. Polydora ligni (Figure VI.18) were several times more abundant in 1988 than preceding years. Nereis (Neanthes) succinea (Figure VI.19) were mostly associated with plant material and were abundant in cold seasons of all years except 1985. Hobsonia florida (Figure VI.20) were equally abundant in all habitats, peaked in the winter of 1986 then declined. Heteromastus filiformis (Figure VI.21) were equally abundant in all habitats but more abundant in 1988 than preceding

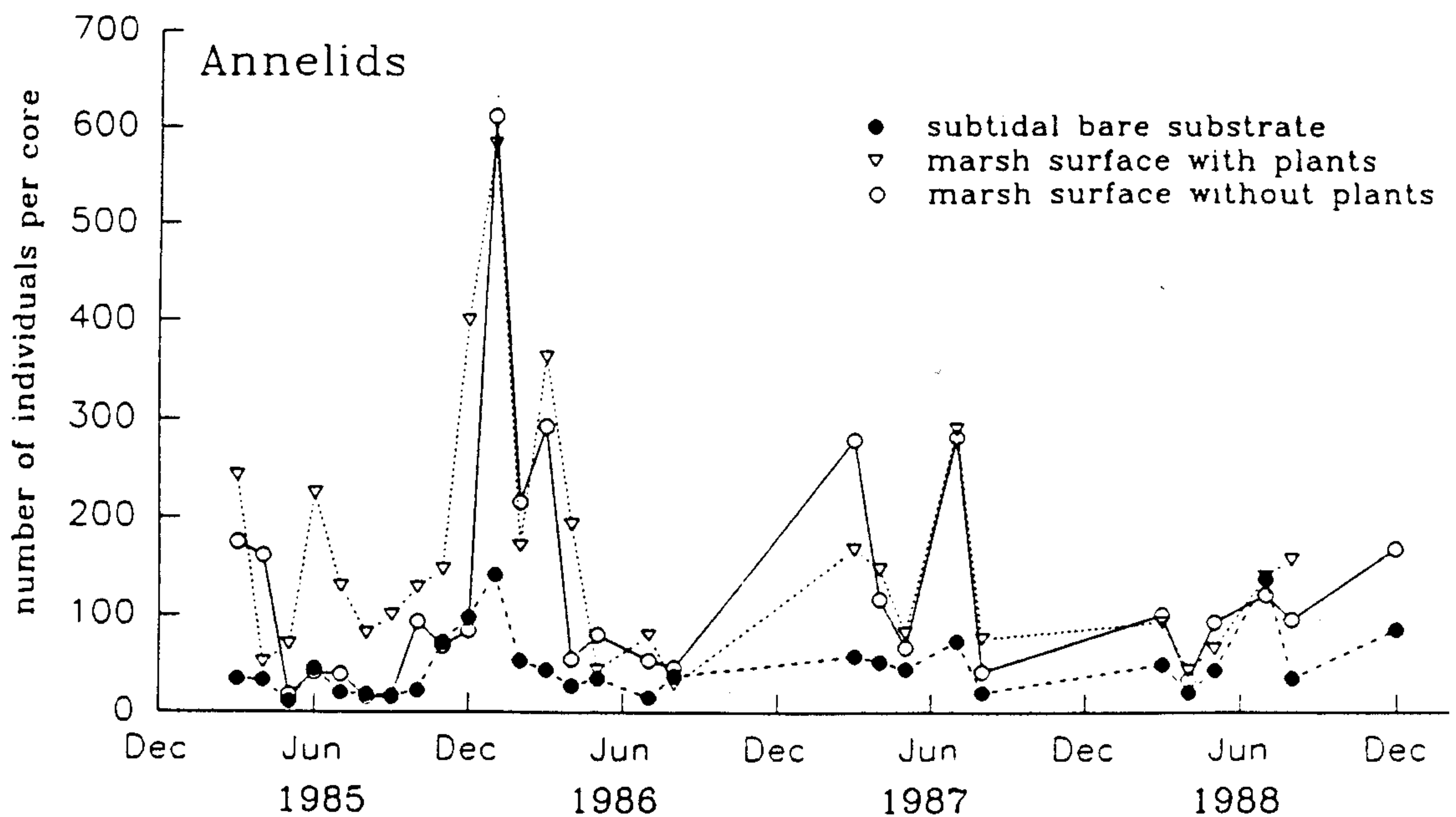


Figure VI.8. Mean abundances of annelids in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

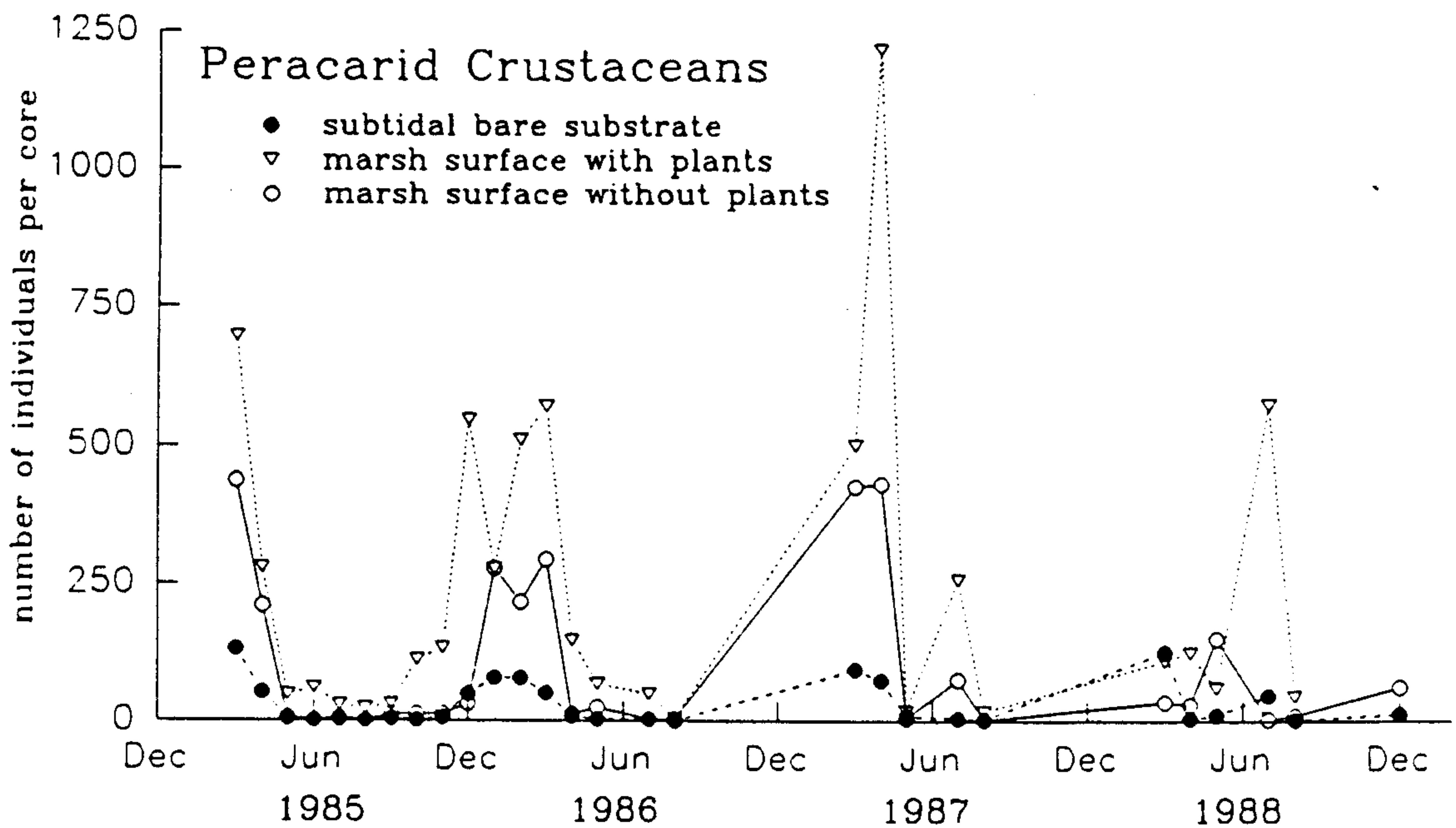


Figure VI.9. Mean abundances of infaunal crustaceans in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

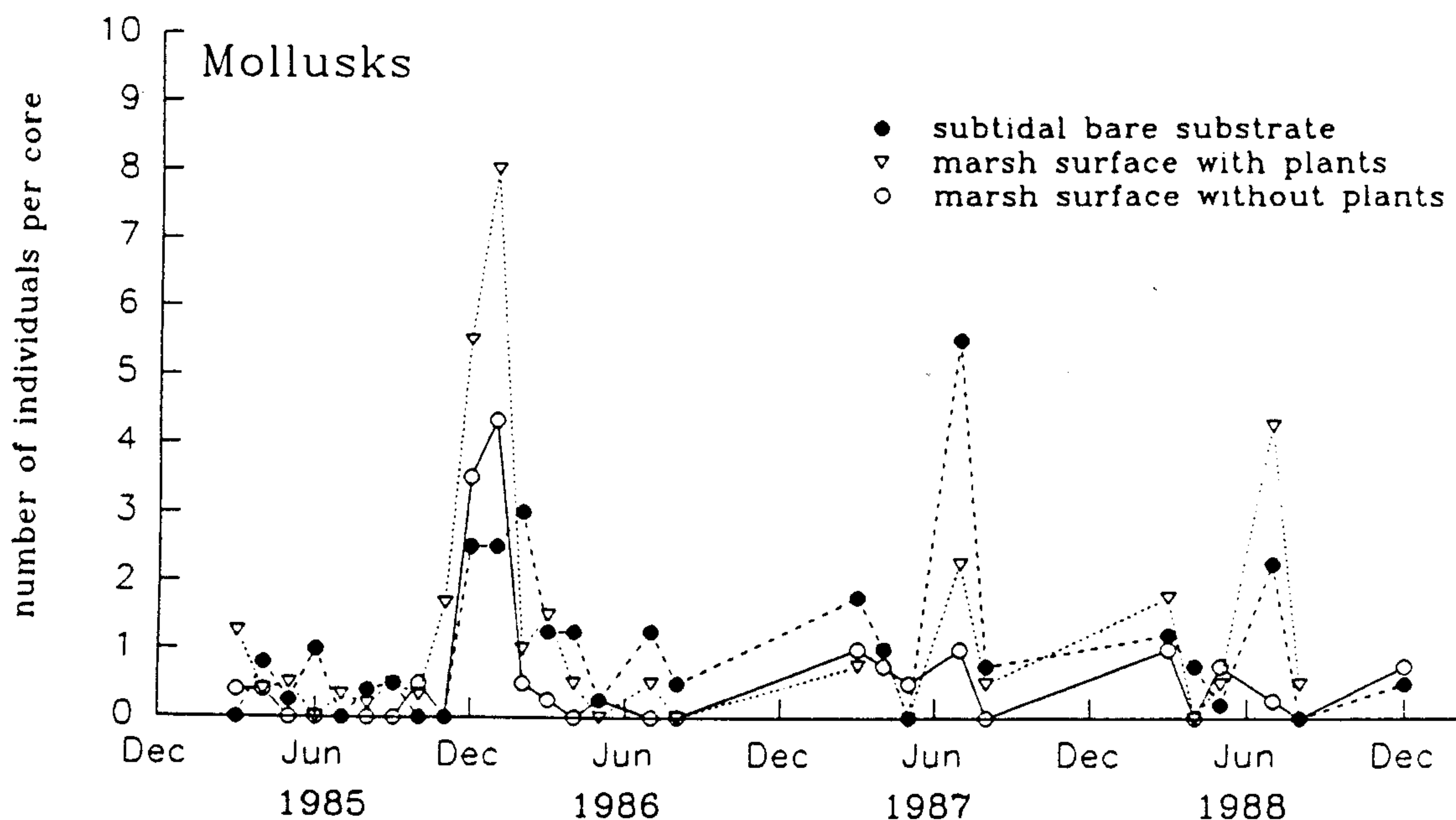


Figure VI.10. Mean abundances of infaunal mollusks in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

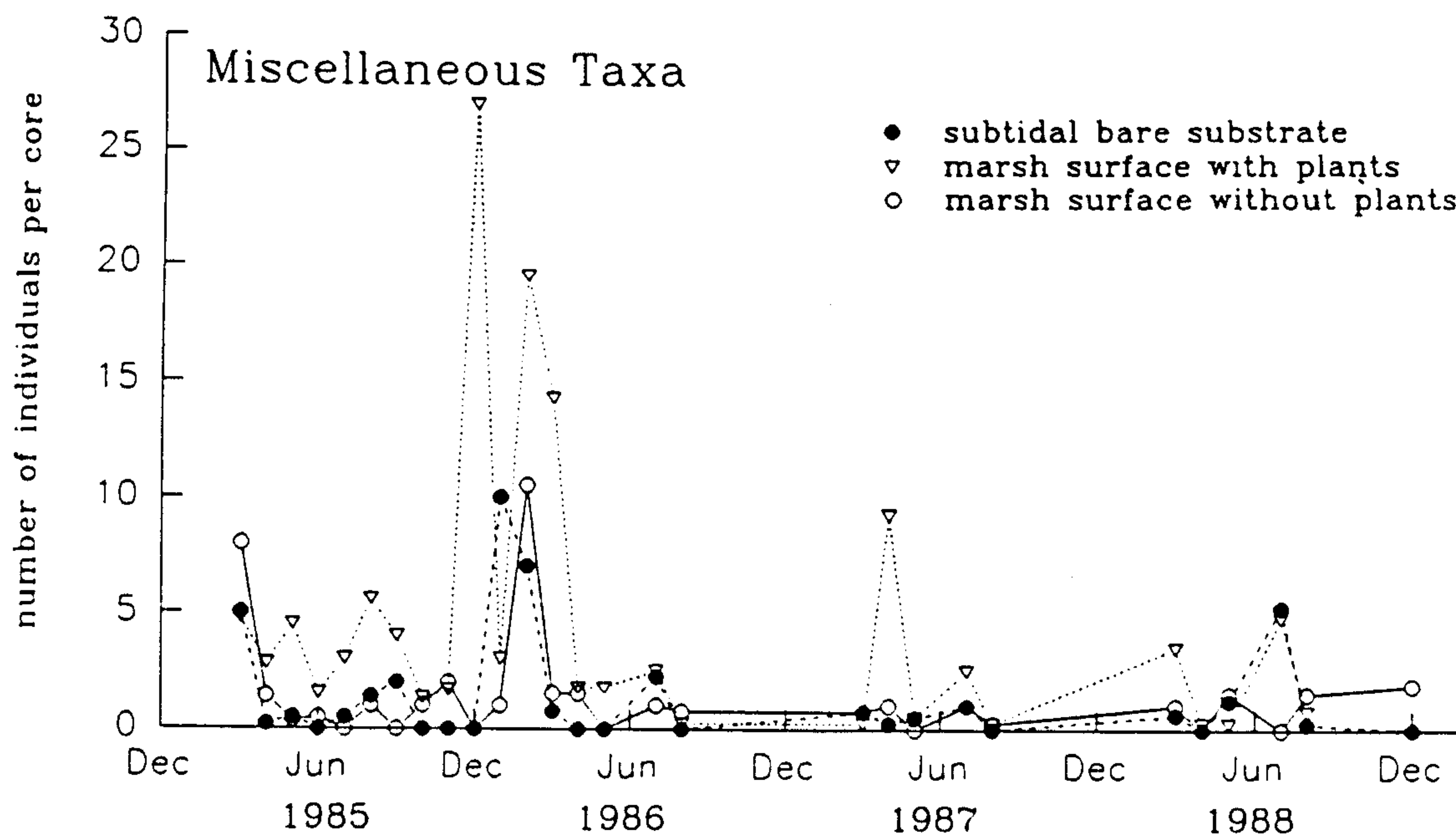


Figure VI.11. Mean abundances of other taxonomic groups in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

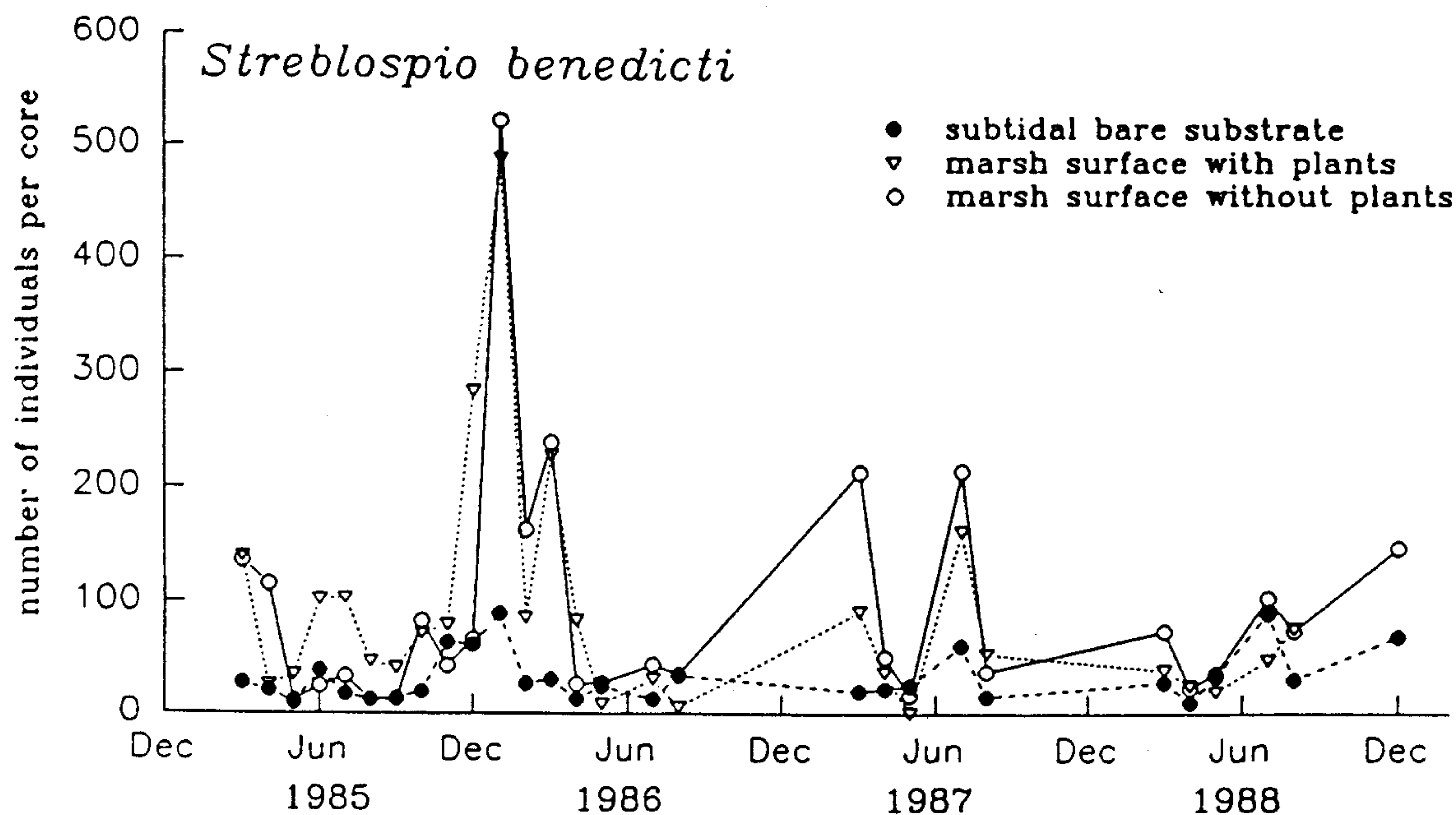


Figure VI.12. Mean abundances of *Streblospio benedicti* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

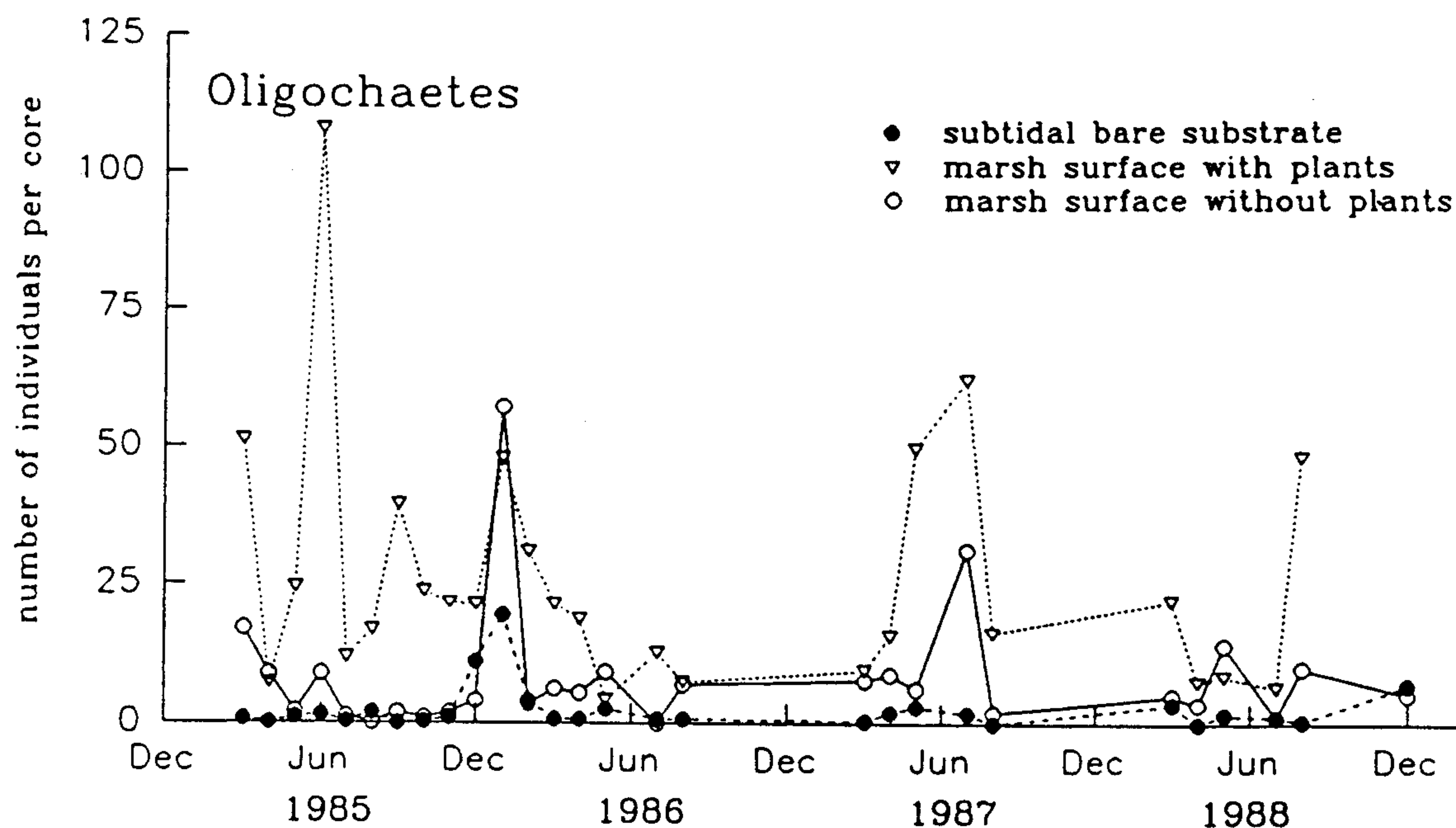


Figure VI.13. Mean abundances of oligochaetes (*Oligochaeta*) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

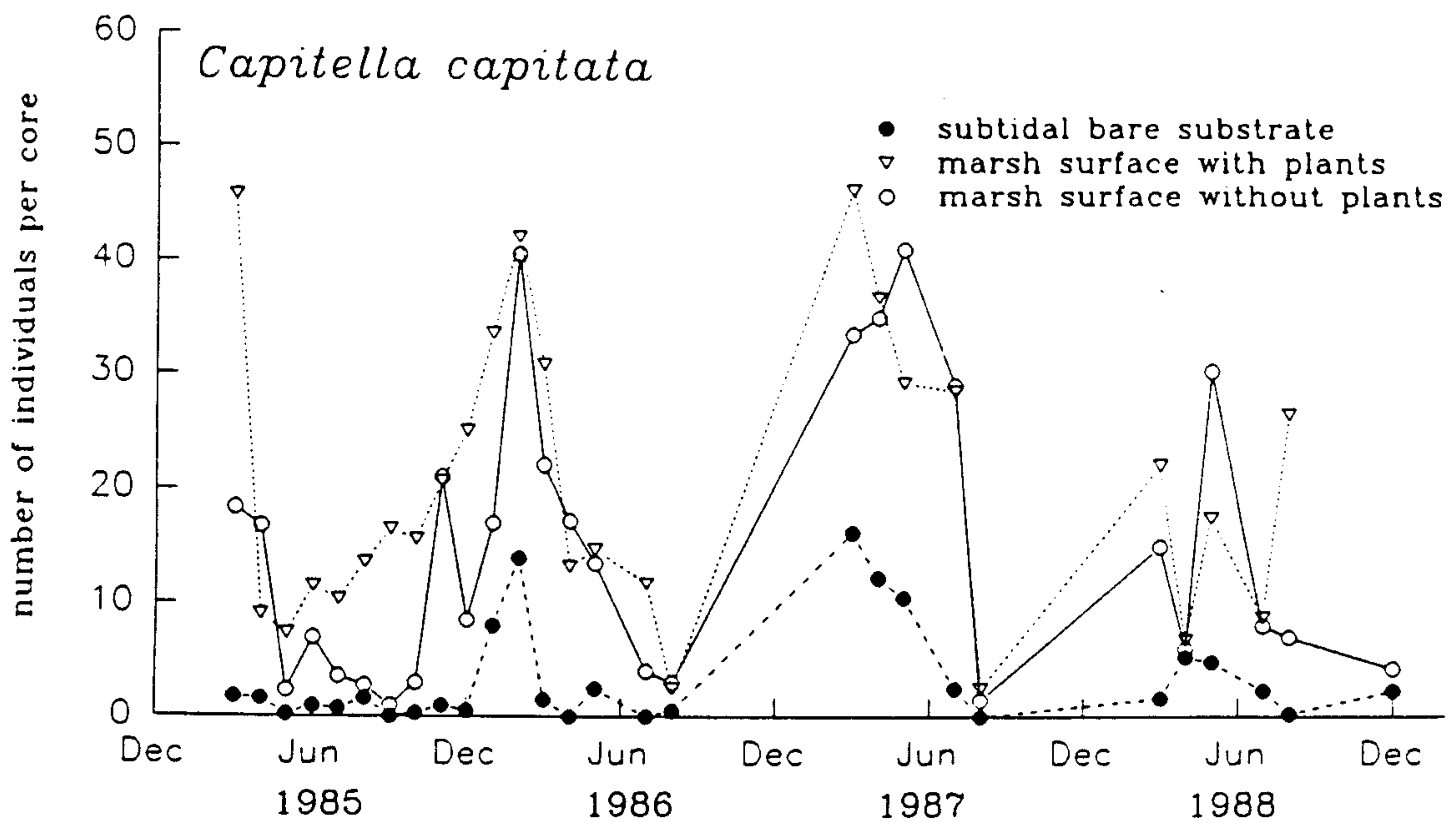


Figure VI.14. Mean abundances of *Capitella capitata* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

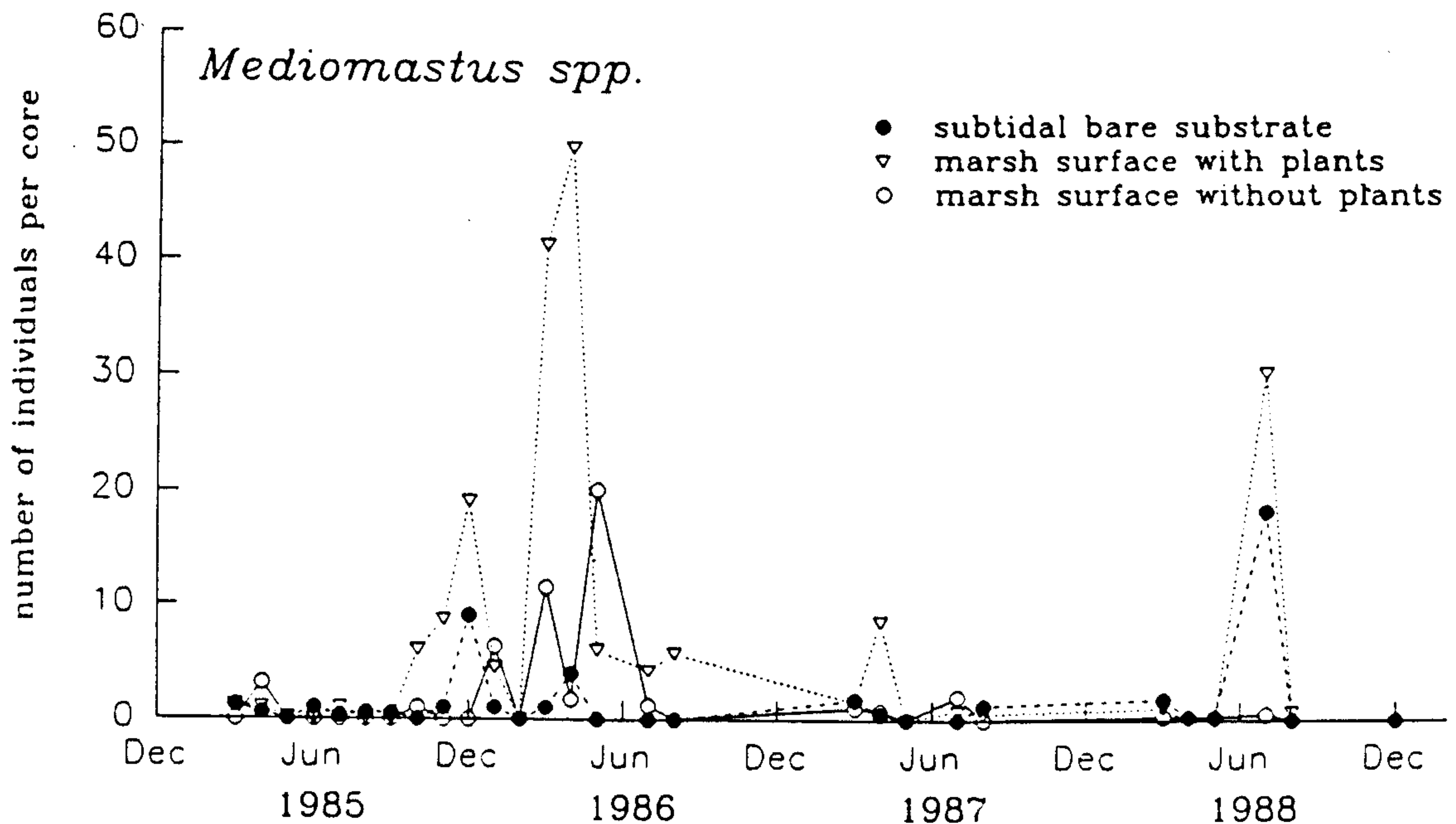


Figure VI.15. Mean abundances of *Mediomastus* spp. (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

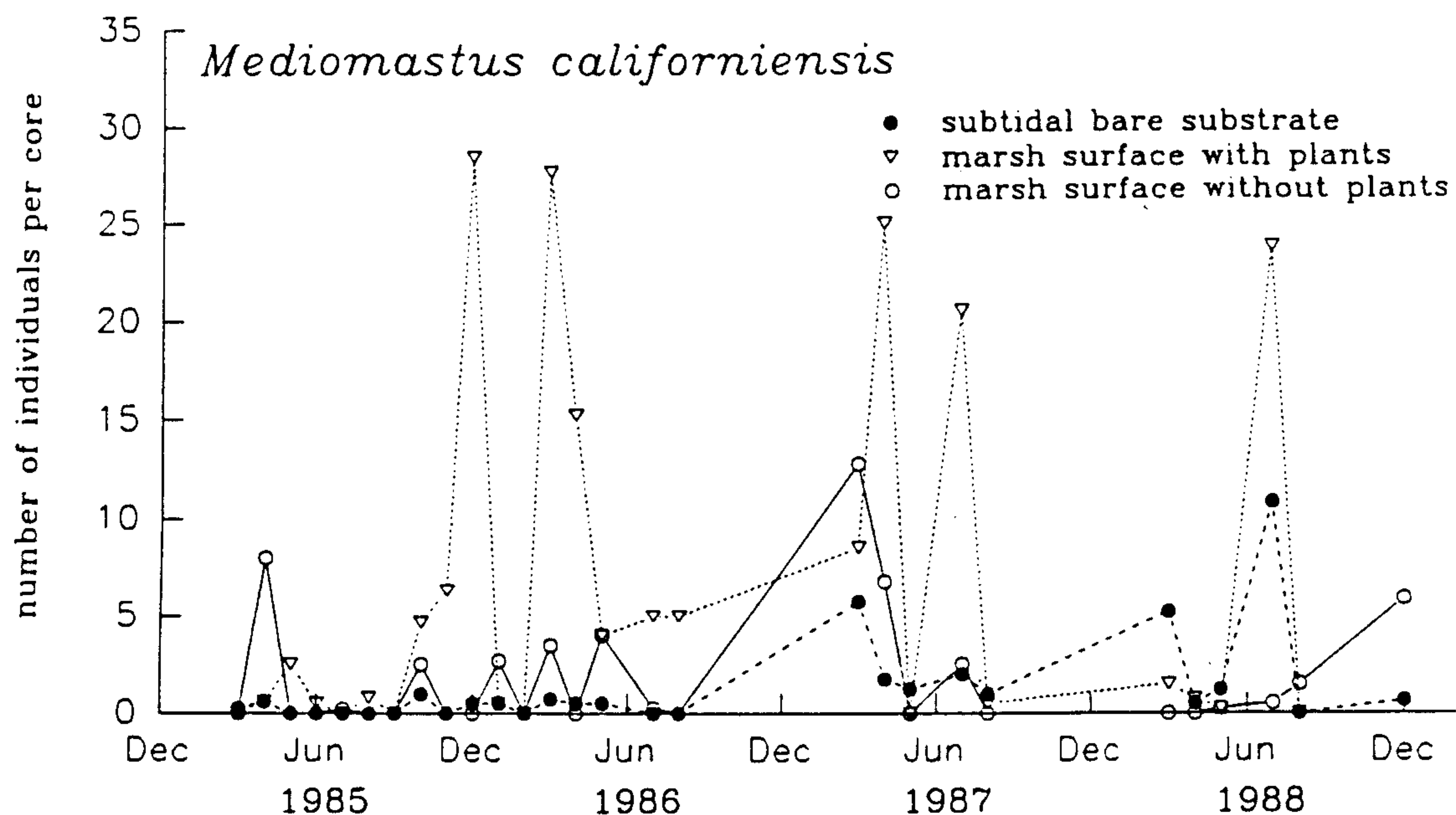


Figure VI.16. Mean abundances of *Mediomastus californiensis* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

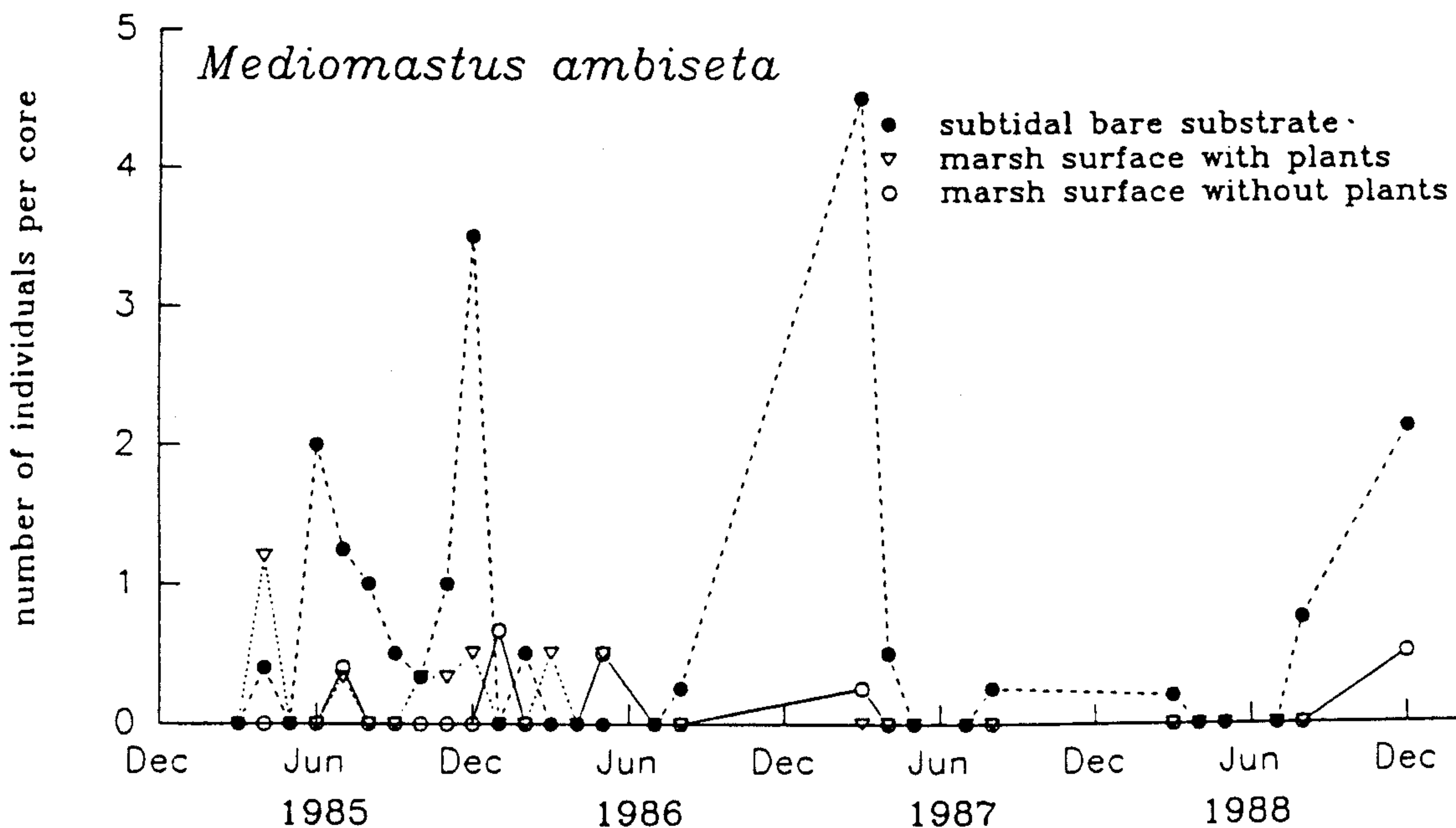


Figure VI.17. Mean abundances of *Mediomastus ambiseta* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

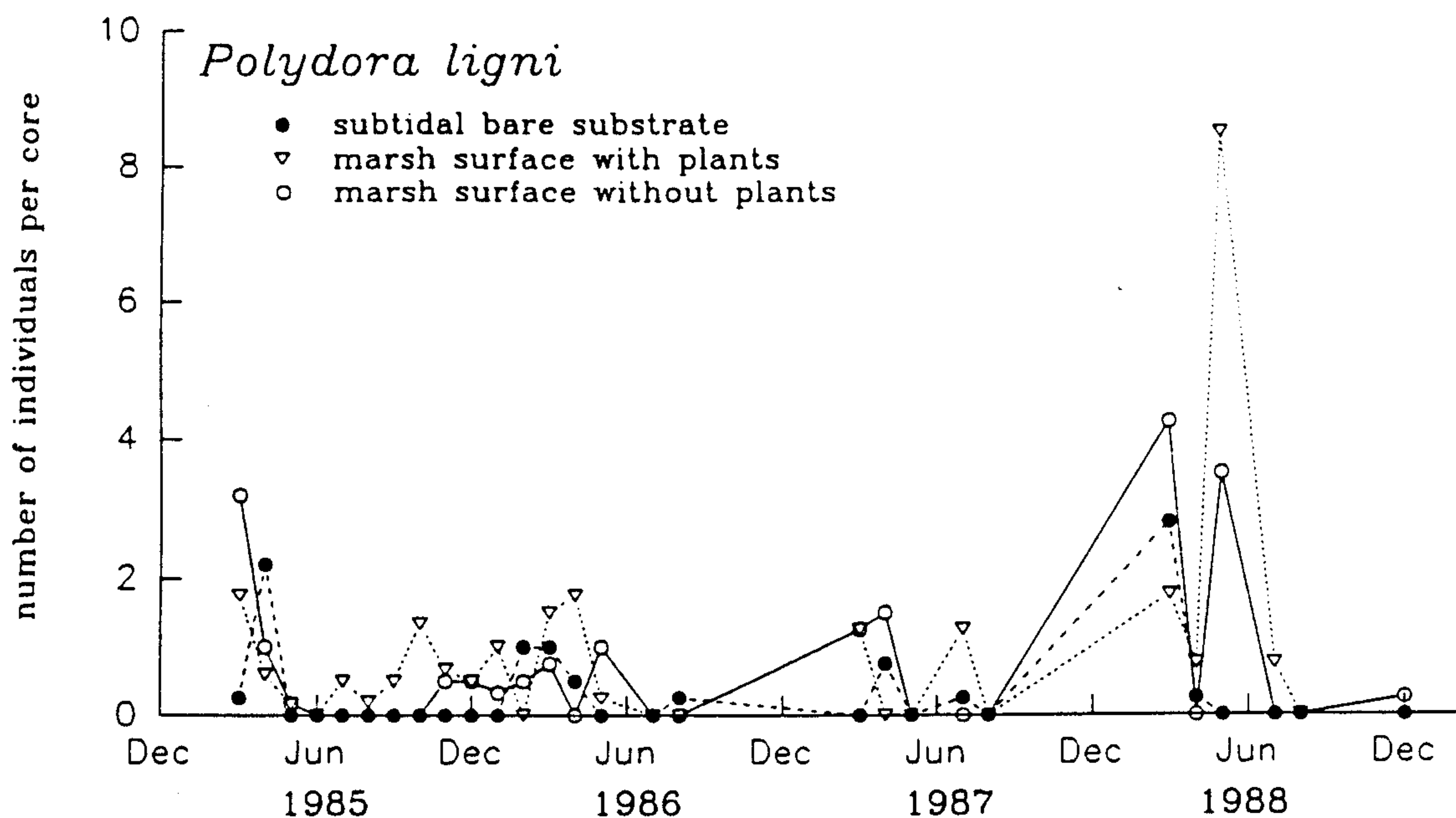


Figure VI.18. Mean abundances of *Polydora ligni* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

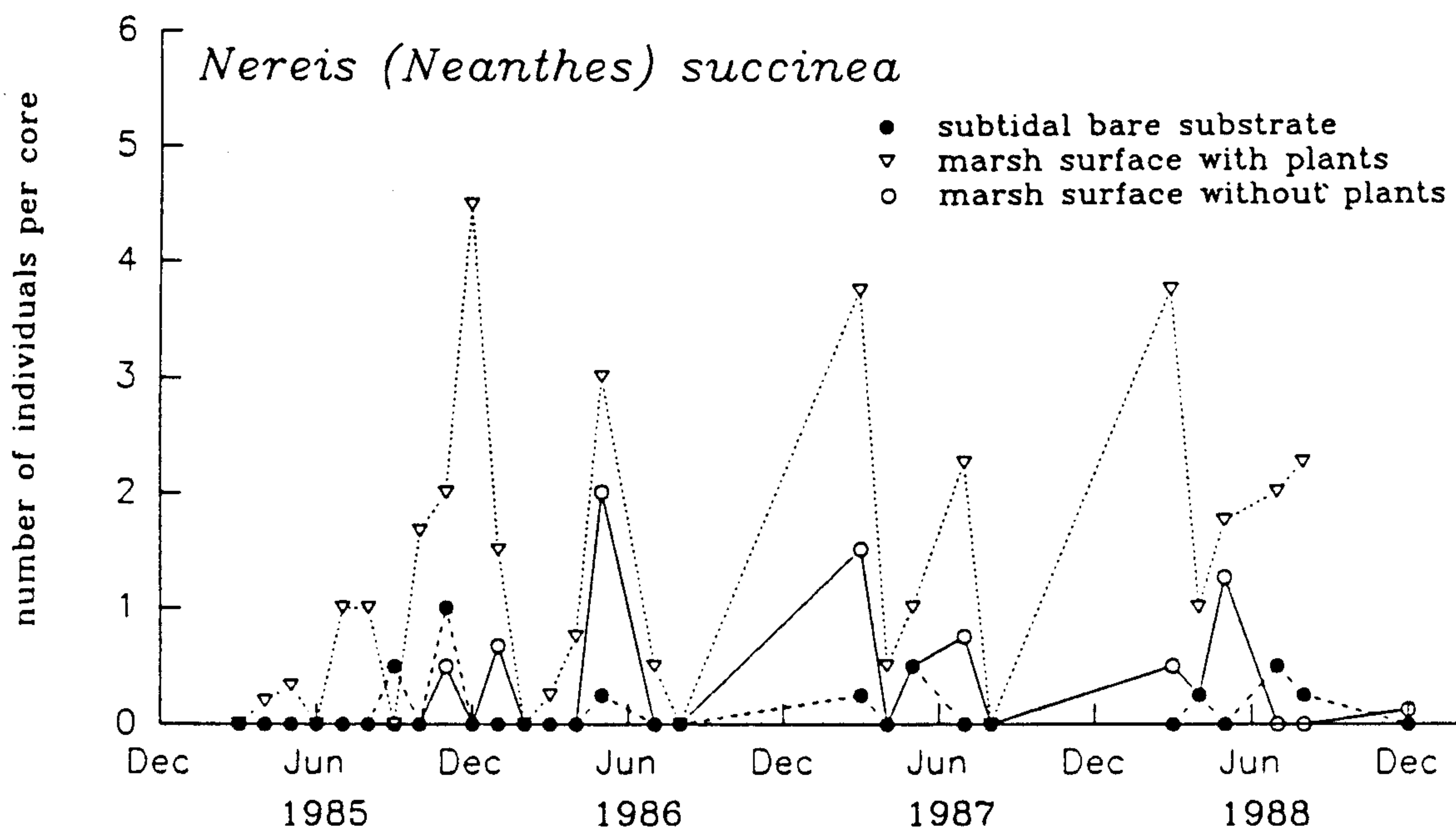


Figure VI.19. Mean abundances of *Nereis (Neanthes) succinea* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

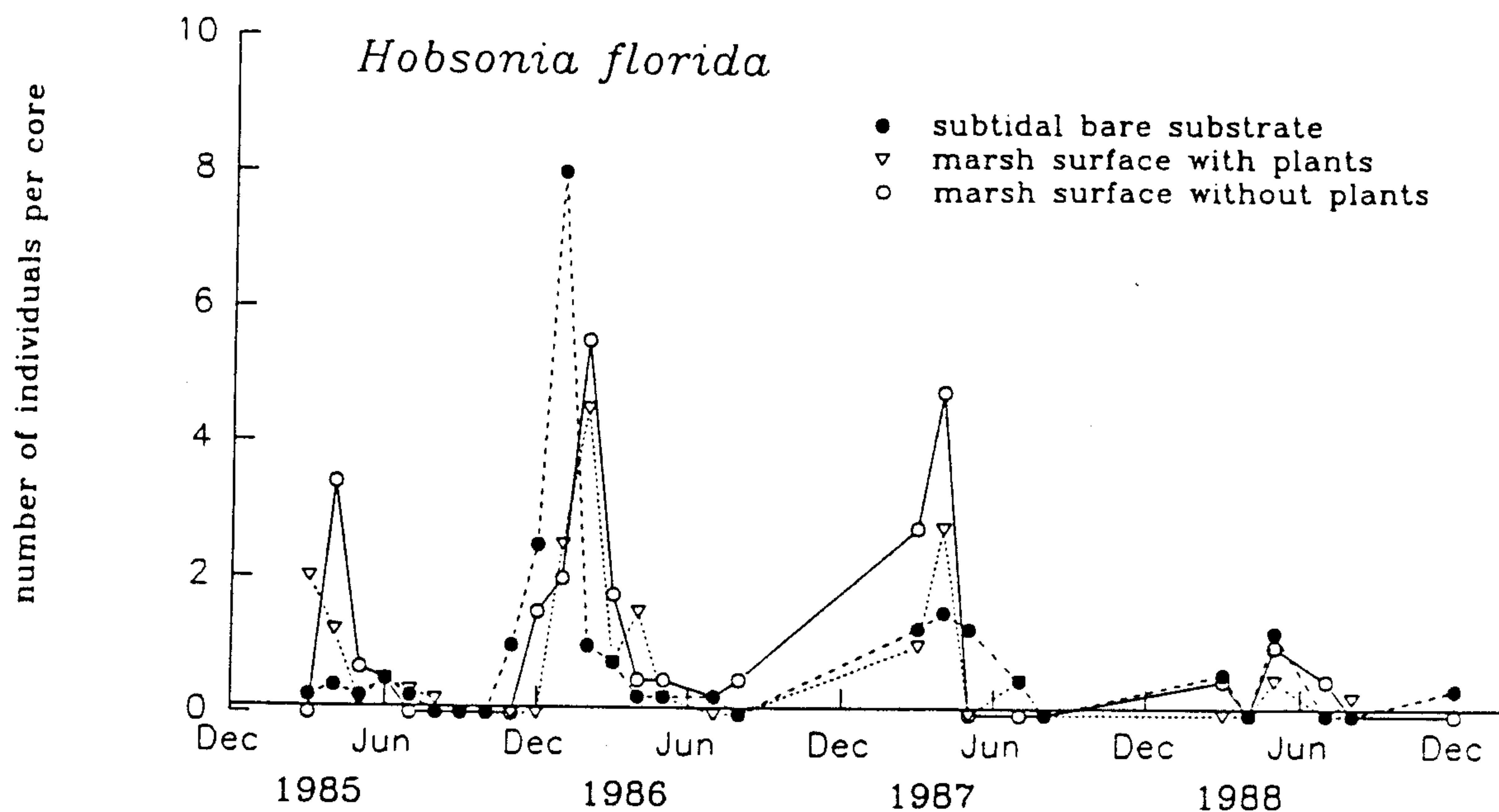


Figure VI.20. Mean abundances of *Hobsonia florida* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

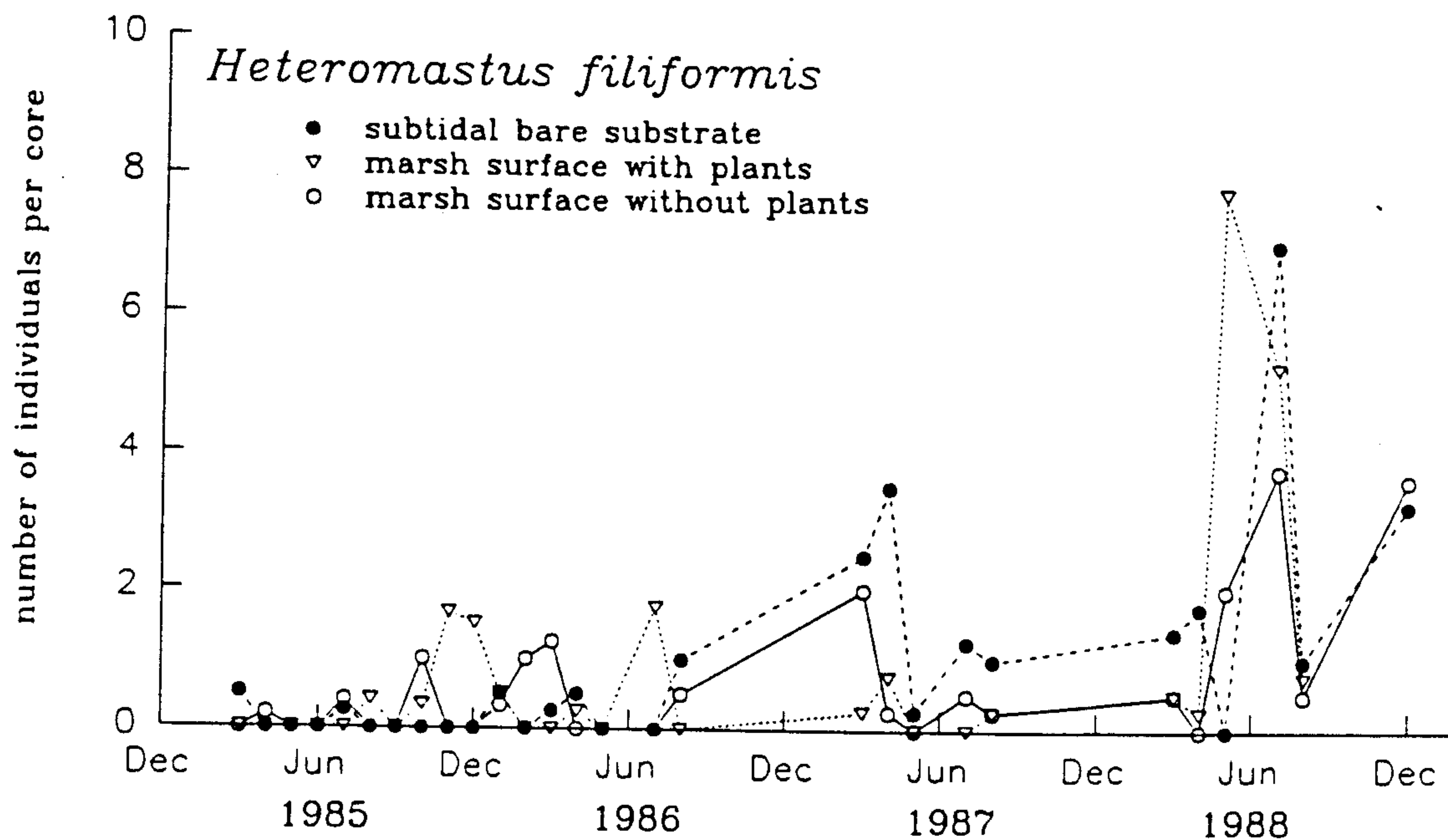


Figure VI.21. Mean abundances of *Heteromastus filiformis* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

years. Thyrag setigera (Figure VI.22) were more abundant subtidally, peaked in 1986 but declined by 1988. Melinna maculata (Figure VI.23) were about the same abundance in all habitats, except that in 1985 and 1986 more were directly associated with marsh plants.

Peracaridean Crustaceans

Peracarids (Figure VI.9) reflected the overall seasonal pattern of infauna even more closely than annelids. Cold season increases were regularly followed by warm season decline in abundances. Peracarids were usually, but not always, more abundant in association with marsh plants.

Hargeria rapax (Figure VI.24), a tanaidacean, were abundant on the marsh surface and highly associated with plant material. This species was low in abundance on subtidal substrate. The next three ranked peracarids were amphipoda. Corophium sp. (Figure VI.25) were also associated with the marsh surface and low in abundance on subtidal substrate. Gammarus mucronatus (Figure VI.26) were highly associated with plants, usually but not always on the marsh surface. High densities of G. mucronatus on subtidal substrate in March 1987 were due association with a macroalgae. Ampelisca abdita (Figure VI.27) were associated with bare subtidal substrate. Cold season densities of Ampelisca were always high on subtidal bottom. Edotea montosa (Figure VI.28), an isopod, were equally abundant between the marsh and subtidal habitat, and abundance in 1985 was low compared to following years. Grandidierella bonneroides (Figure VI.29) were associated with the marsh surface, but densities were high only in the cold seasons of 1987 and 1988. Melita nitida (Figure VI.30) only occurred in high abundance (in association with marsh plants) in July of 1988. Orchestia costaricana (Figure VI.31) were strictly associated with marsh plants, peaked in March 1988, but intermittently occurred in other years.

Mollusks

Molluscan infauna (Figure VI.10) did not conform to patterns of overall infaunal abundance. Mollusks were equally abundant among habitats and their seasonal patterns varied considerably among years.

Mollusks were mainly bivalves. Amygdalum papyrium (Figure VI.32) was the dominant bivalve, occurring in highest numbers densities in the marsh and becoming more numerous in 1988 than preceding years. Amygdalum were as abundant in the warm season as in the cold season. Mulinia lateralis (Figure VI.33) were more abundant subtidally. Their highest density occurred in the summer of 1987. A category of unidentified bivalves (Figure VI.34) was abundant subtidally across all years and on the marsh surface in 1985 and 1986. Tagelus sp. (Figure VI.35) were more abundant subtidally. They were absent from the marsh surface in 1985 and increased in numbers in all habitats between 1986 and 1988.

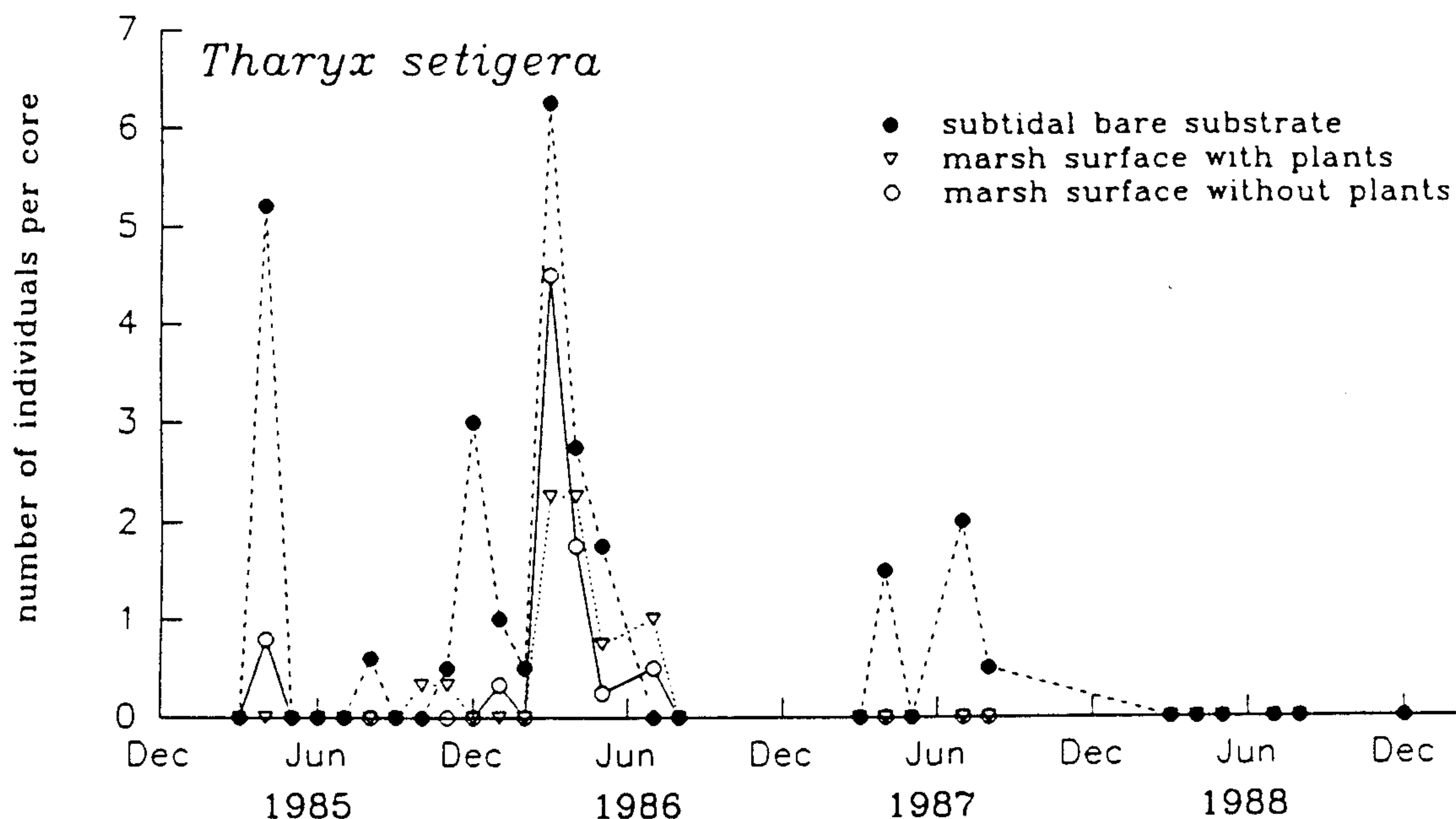


Figure VI.22. Mean abundances of *Tharyx setigera* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

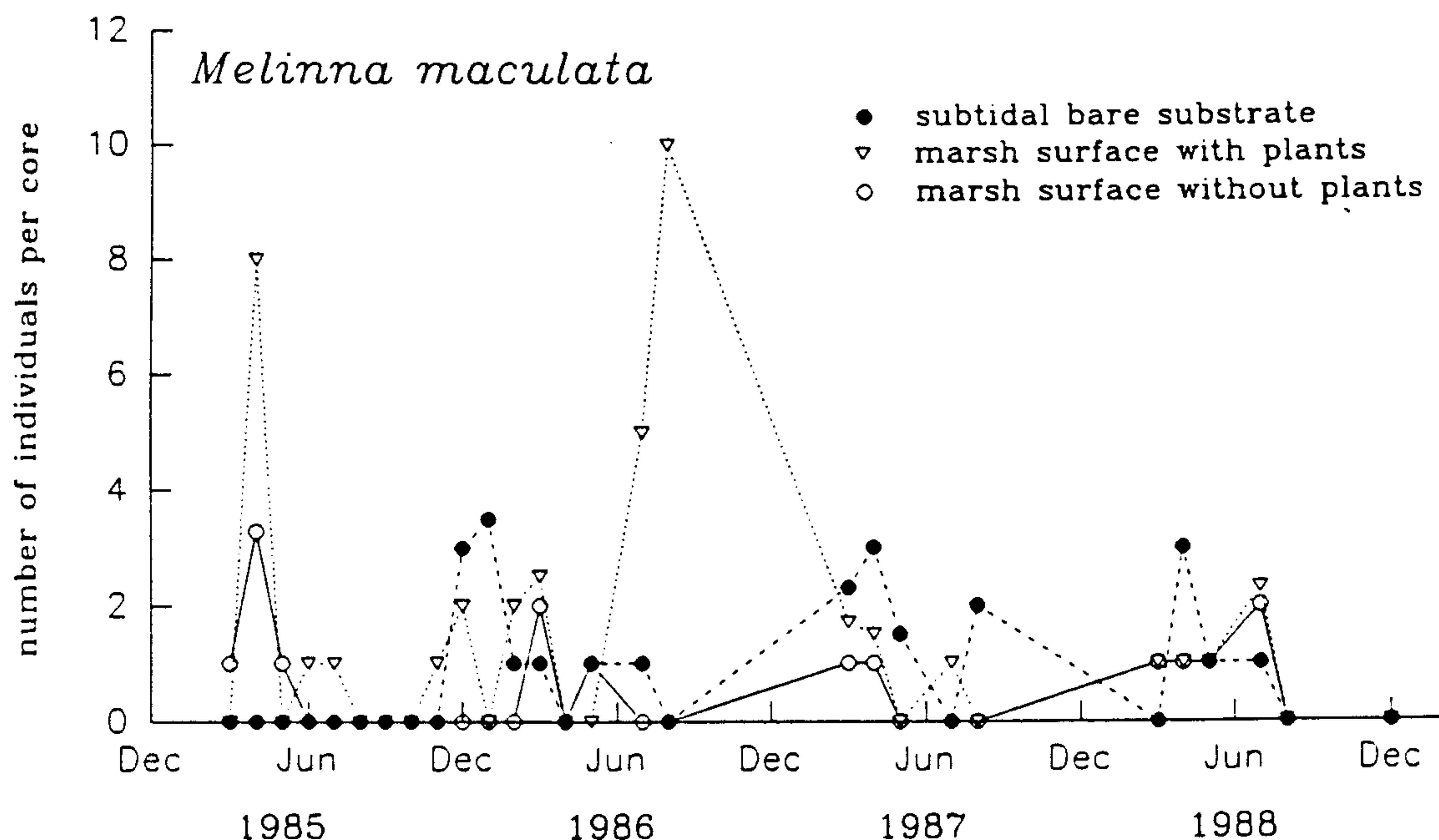


Figure VI.23. Mean abundances of *Melinna maculata* (Polychaeta) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

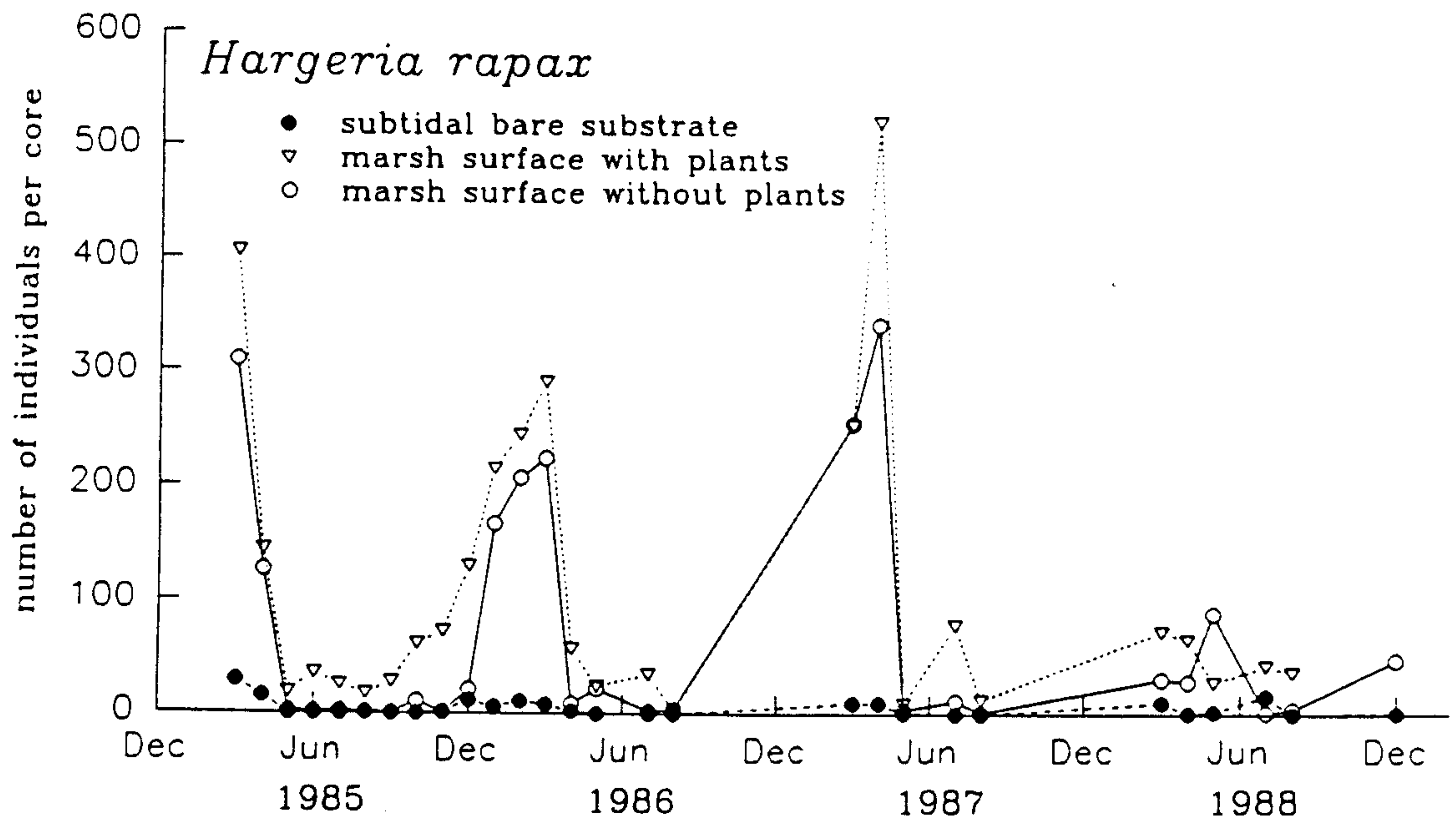


Figure VI.24. Mean abundances of *Hargeria rapax* (Tanaidacea) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

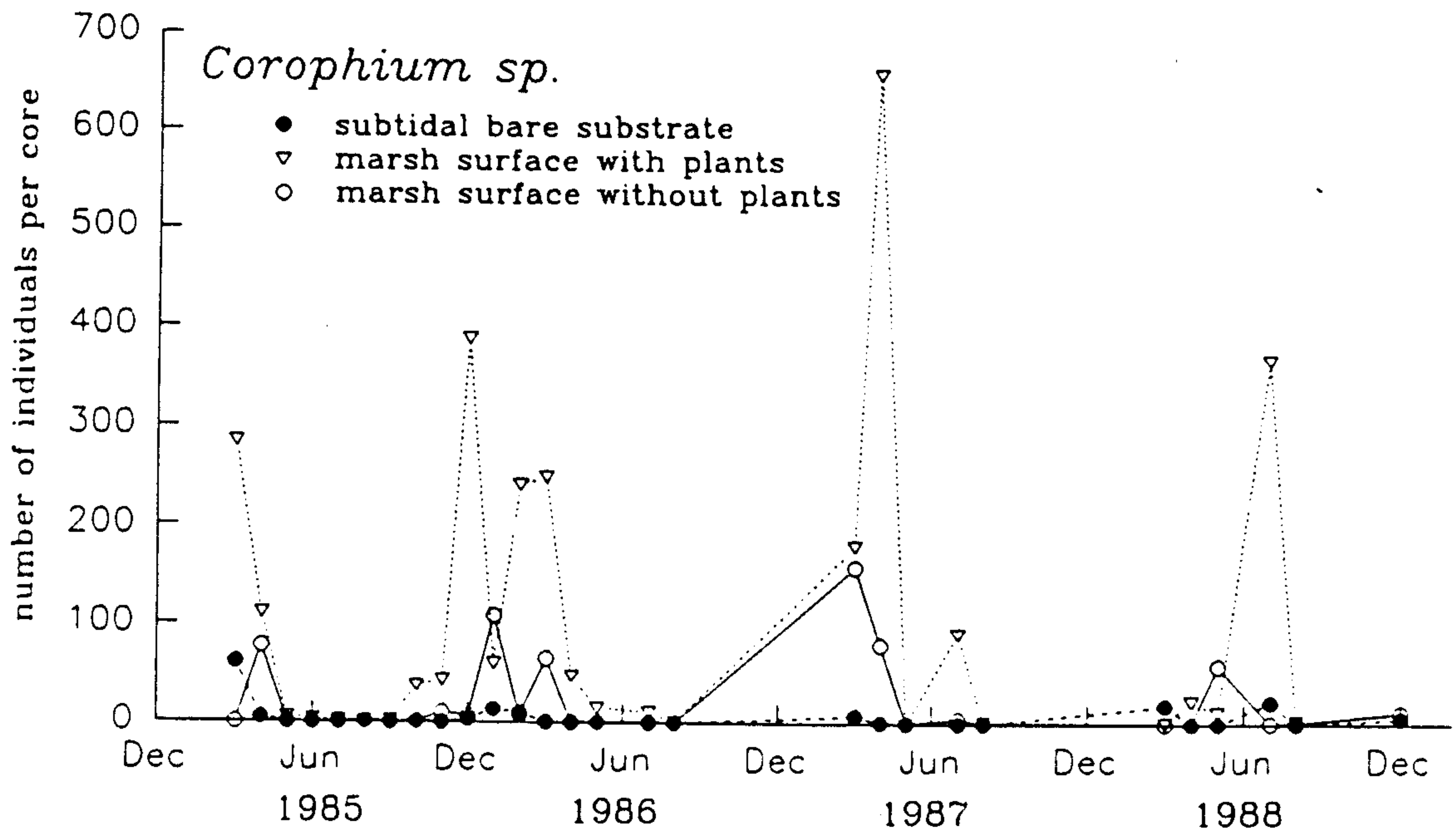


Figure VI.25. Mean abundances of *Corophium sp.* (Amphipoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

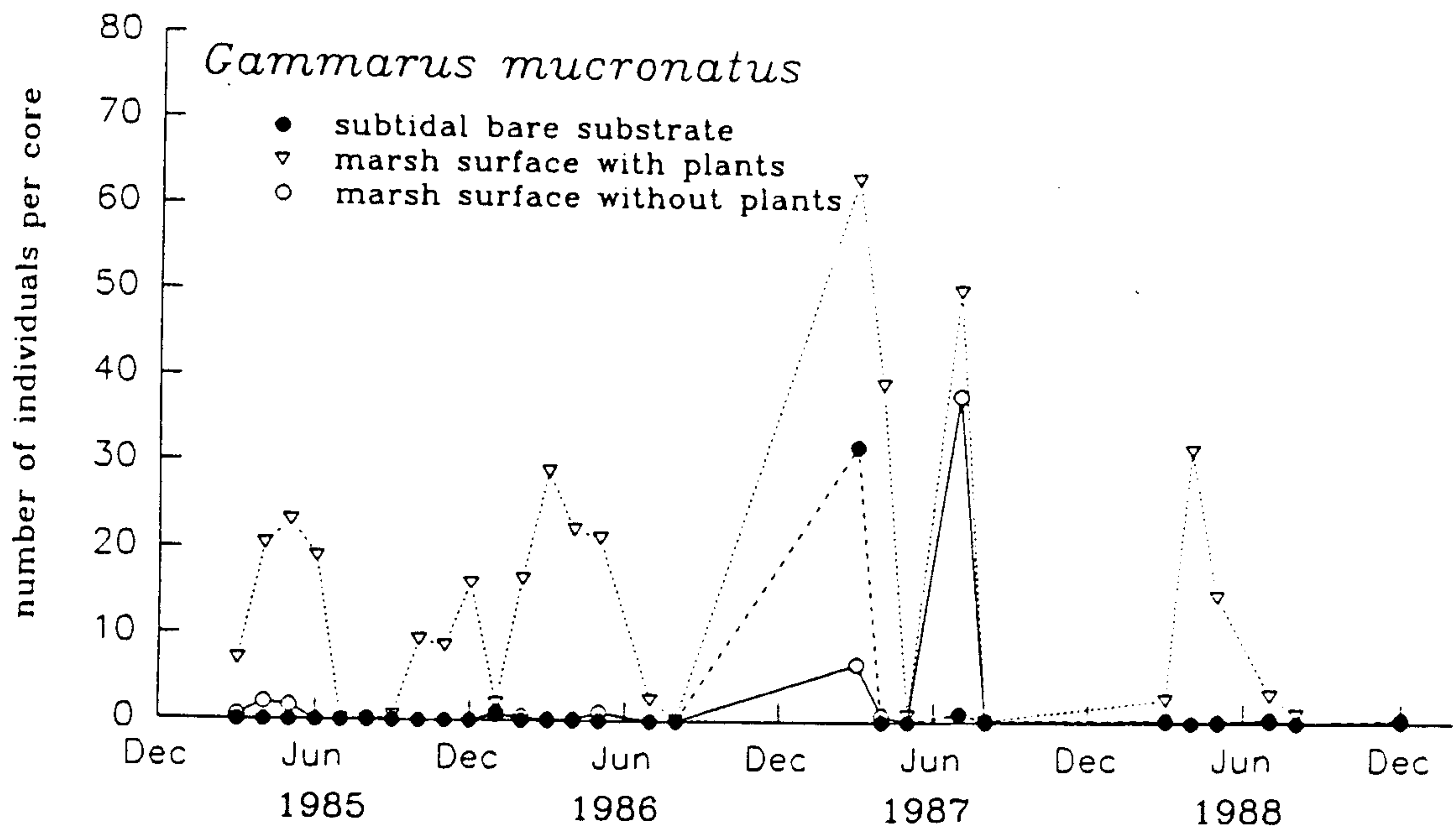


Figure VI.26. Mean abundances of *Gammarus mucronatus* (Amphipoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

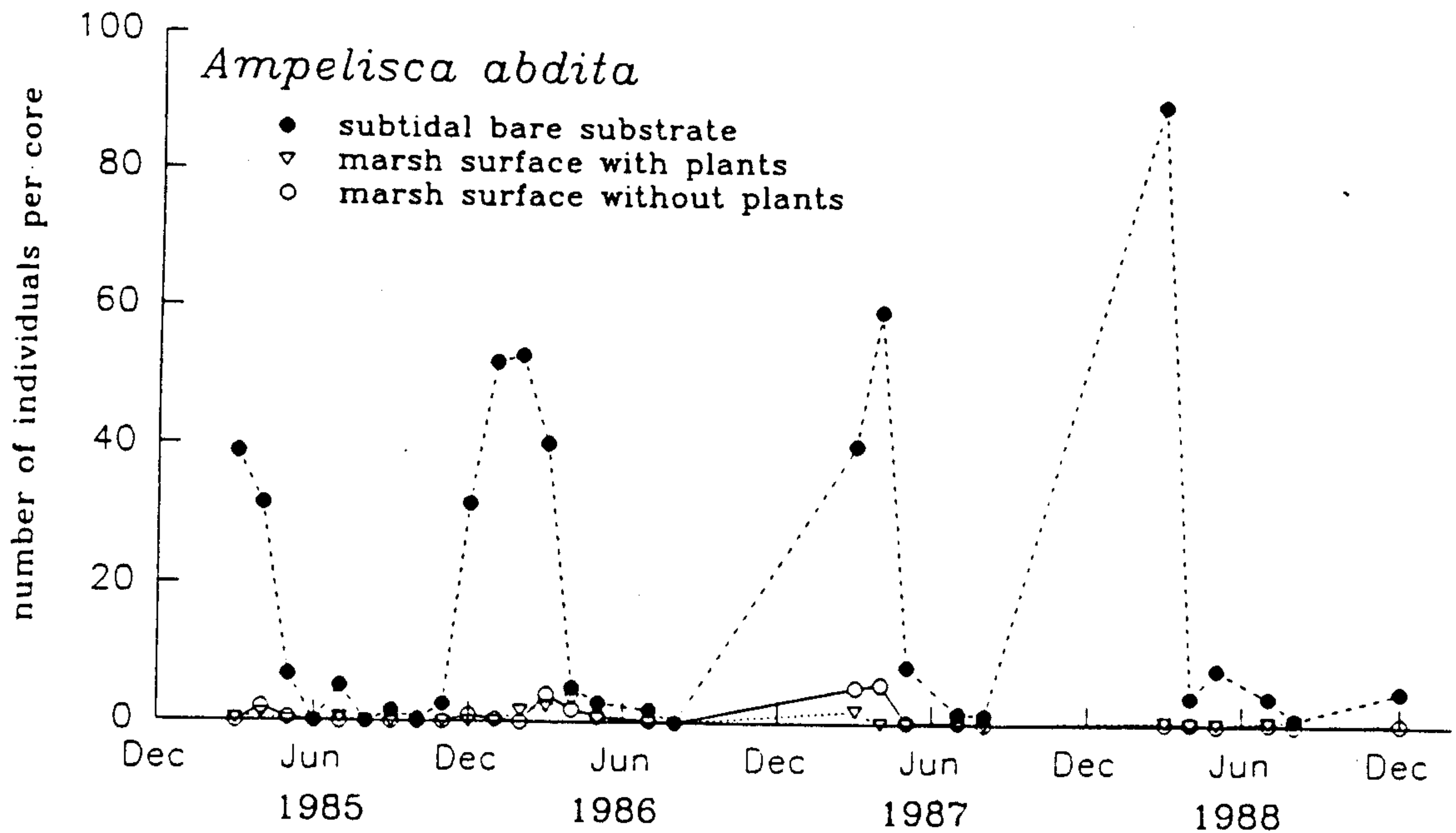


Figure VI.27. Mean abundances of *Ampelisca abdita* (Amphipoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

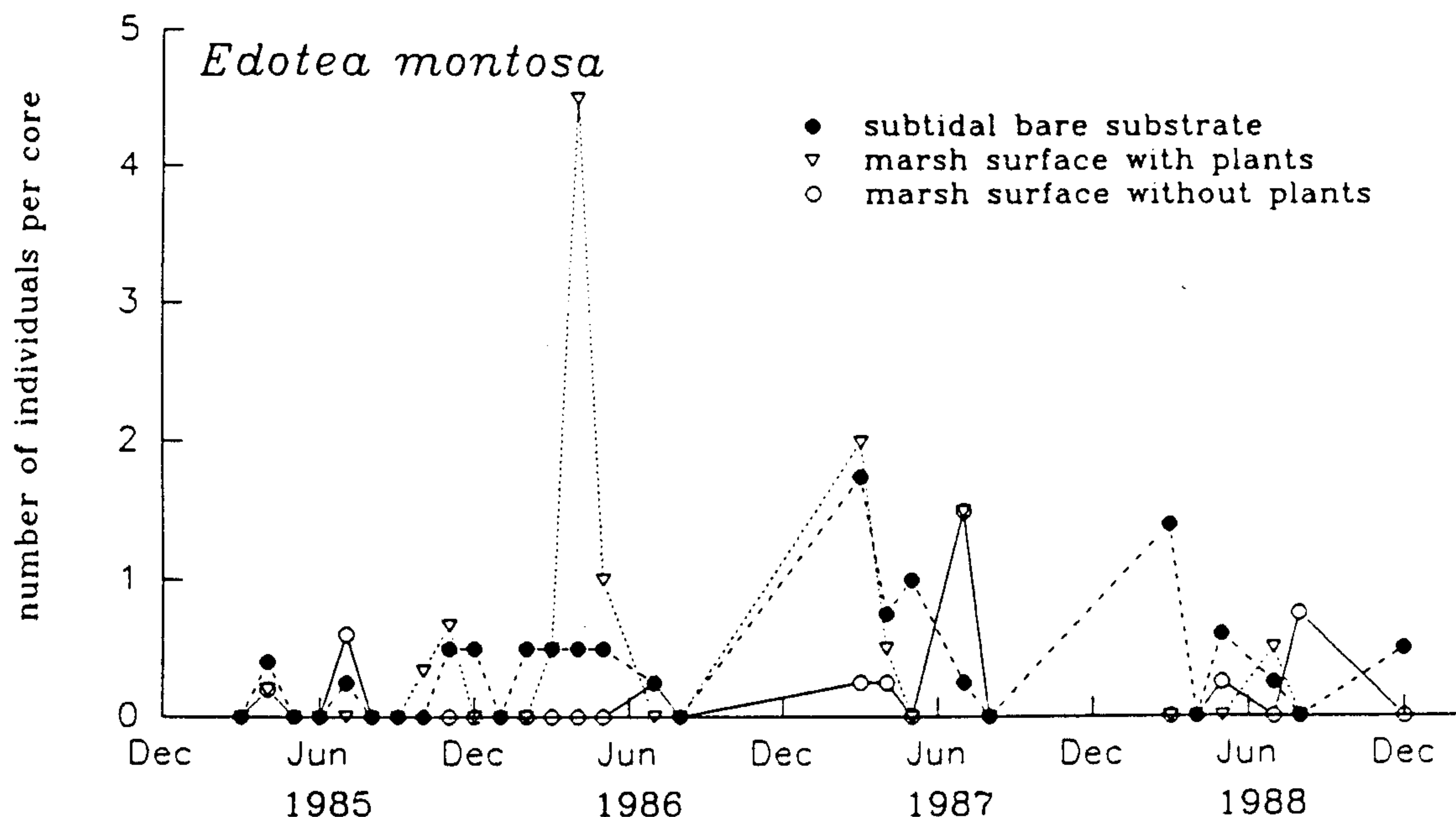


Figure VI.28. Mean abundances of *Edotea montosa* (Isopoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

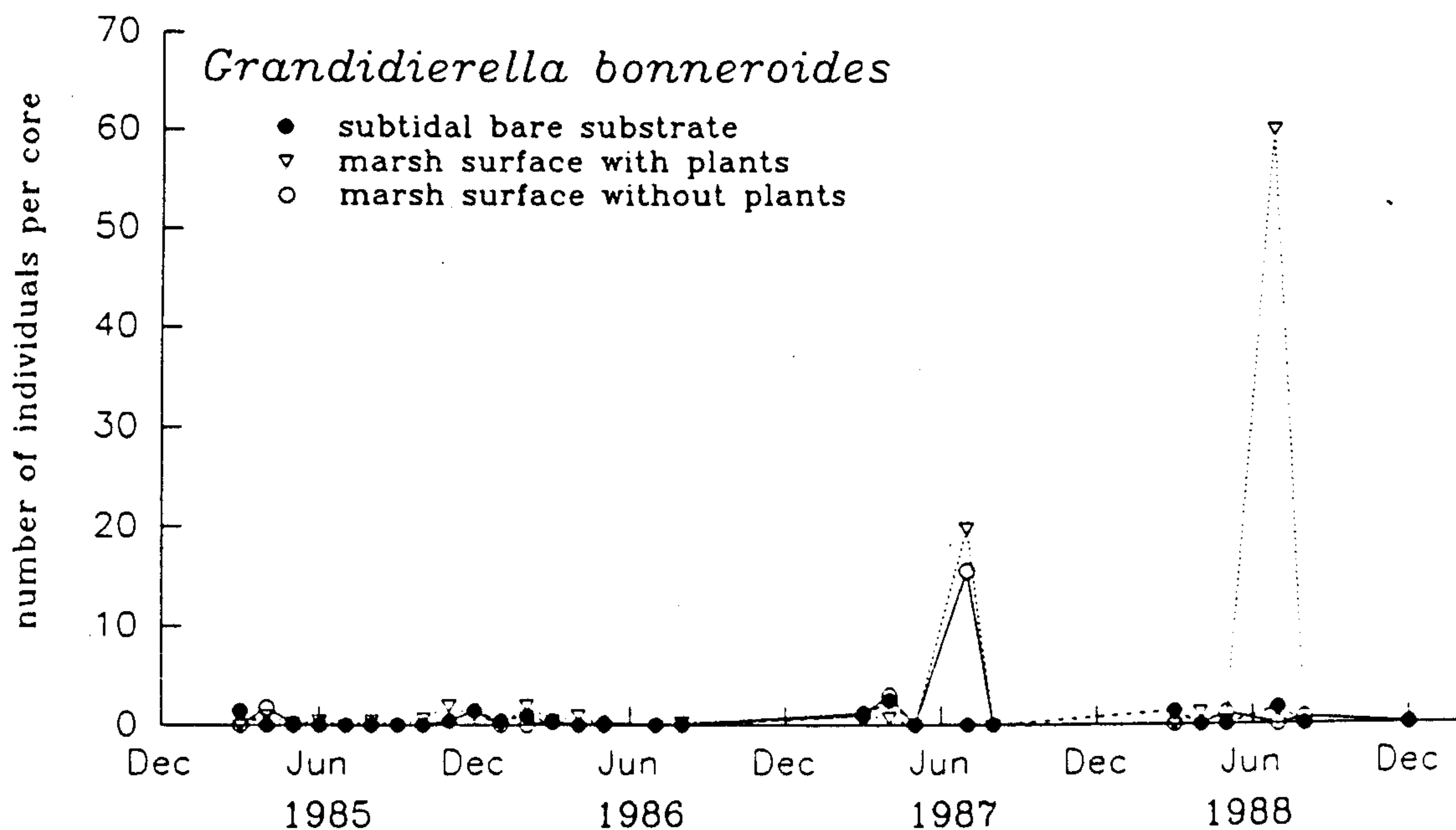


Figure VI.29. Mean abundances of *Grandidierella bonneroides* (Amphipoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

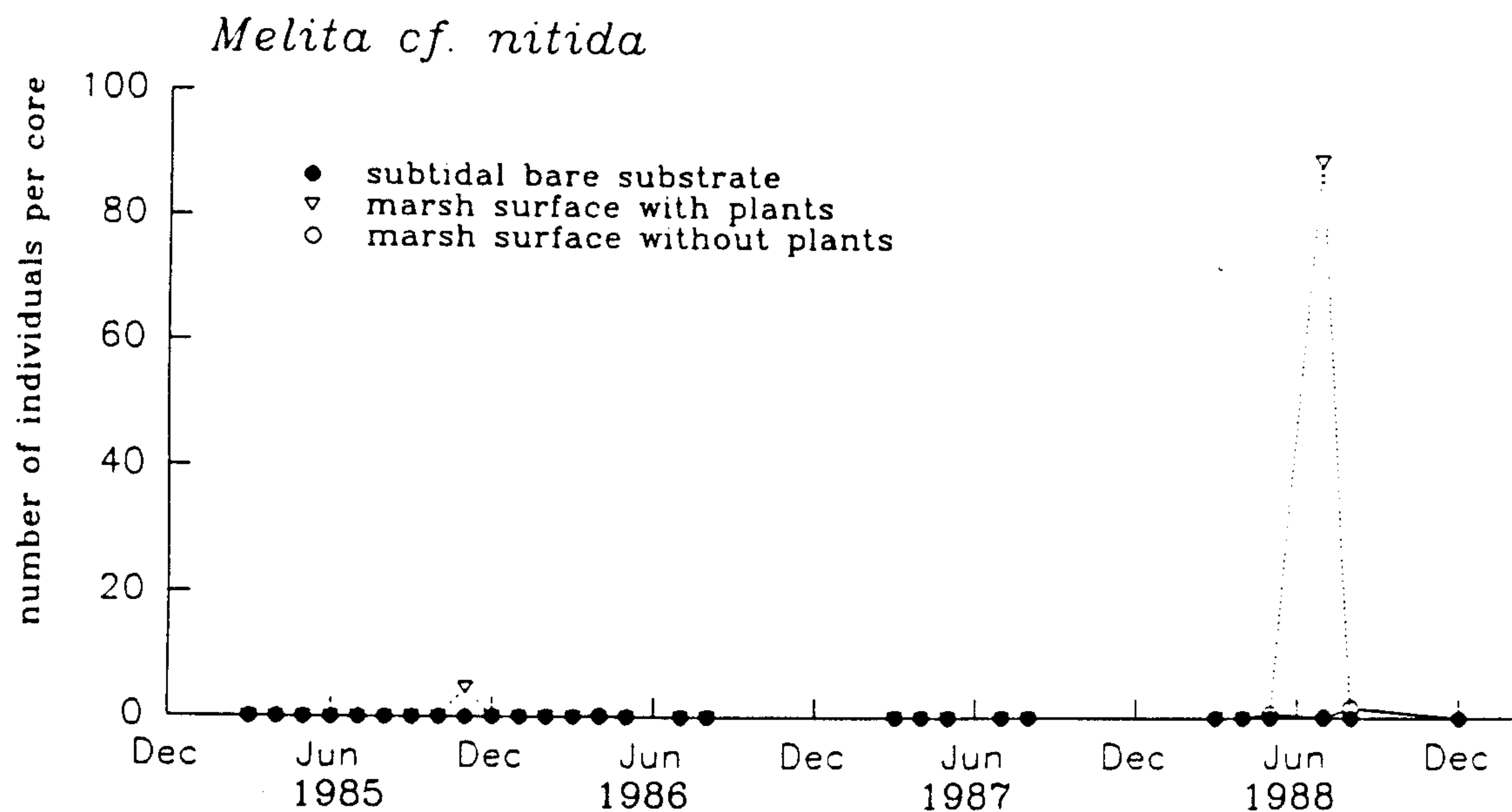


Figure VI.30. Mean abundances of *Melita cf. nitida* (Amphipoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

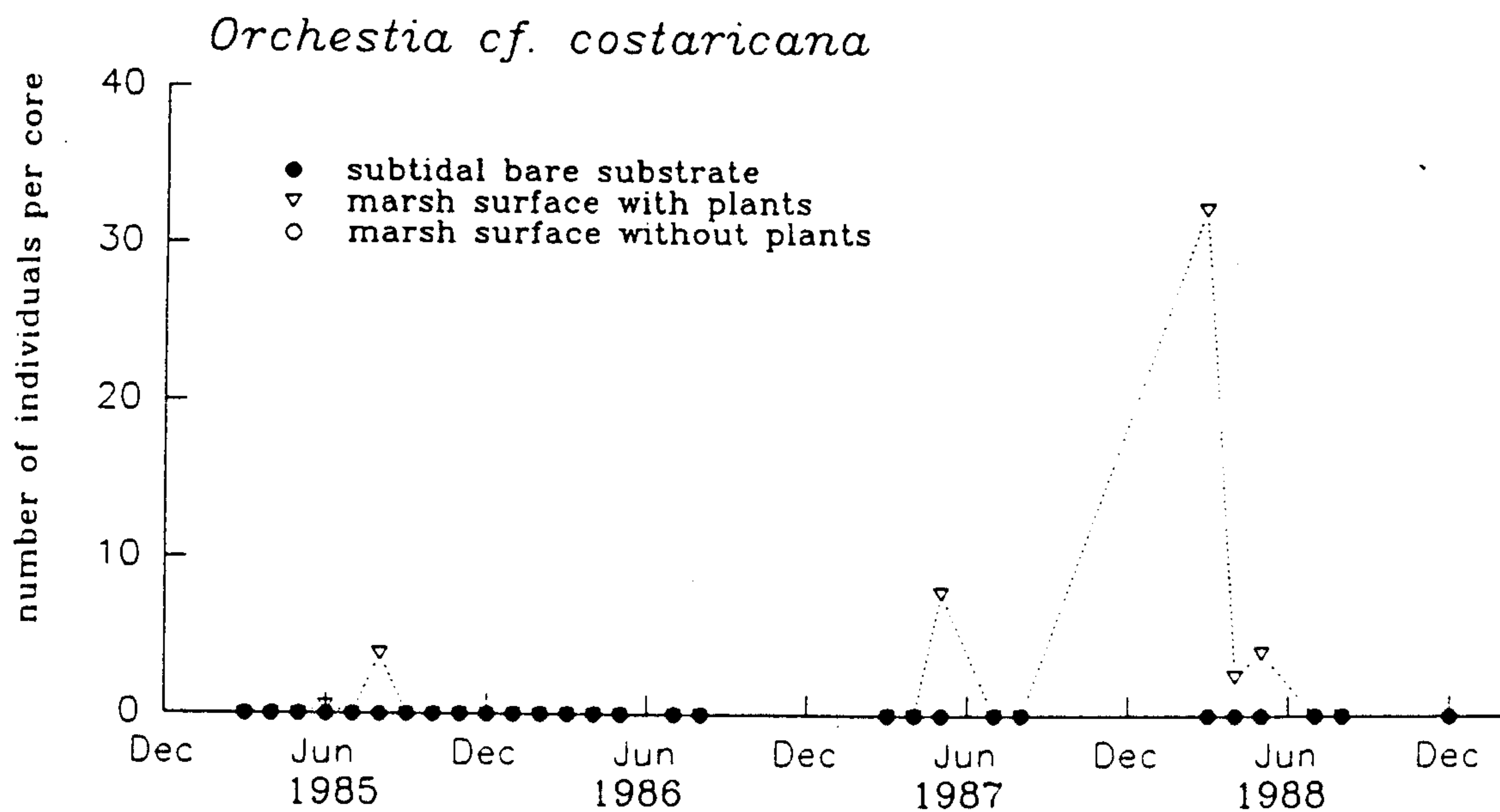


Figure VI.31. Mean abundances of *Orchestia cf. costaricana* (Amphipoda) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

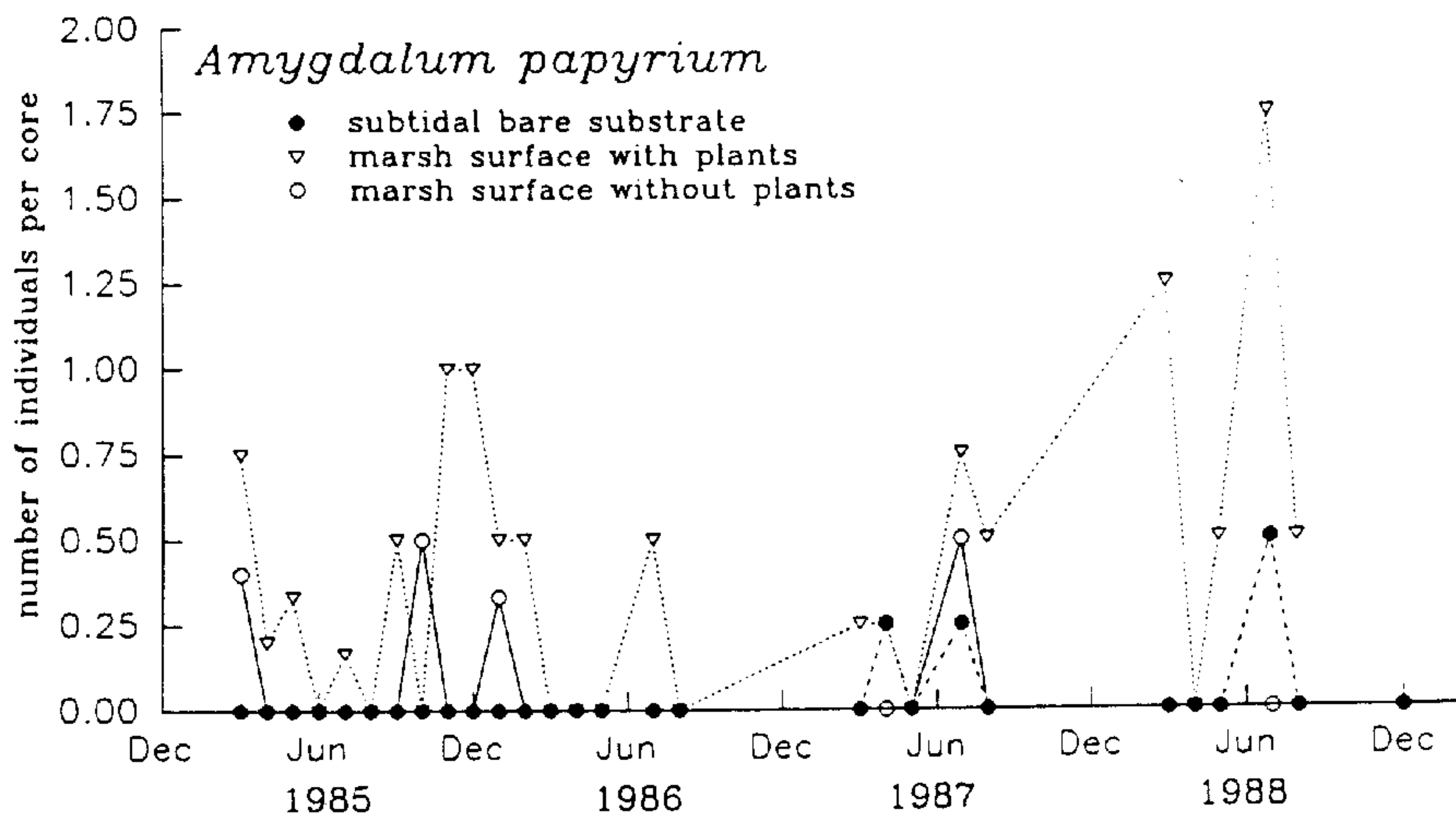


Figure VI.32. Mean abundances of *Amygdalum papyrium* (Bivalvia) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

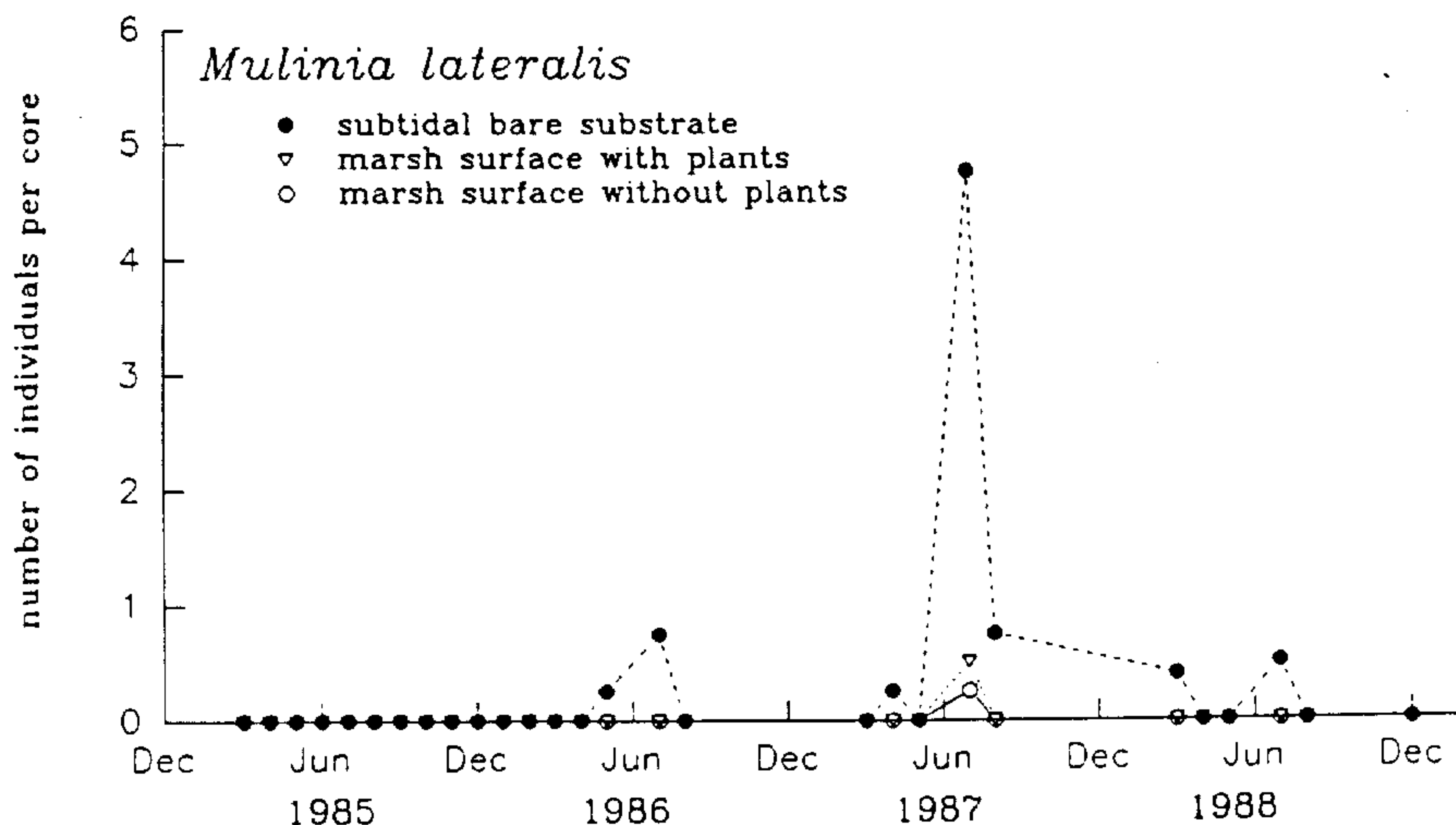


Figure VI.33. Mean abundances of *Mulinia lateralis* (Bivalvia) in three habitats at a salt marsh in West Bay, adjacent to Galveston Island, Texas. Note: These are partial results from those monthly sediment cores from which data were available (78.5 sq.cm each).

Miscellaneous taxa (Figure VI.11) were mainly insect larvae that had abundance patterns similar to all infauna combined. Highest densities were in late winter and early spring. They were usually found in association with plants in the marsh.

DISCUSSION

Dominant Marsh Infauna of the Galveston Estuary

Abundances of marsh infauna in the Galveston Estuary varied with salinity in a 1987 survey (Table 6 in Zimmerman et al. 1990). Dominance among species is available from the survey, although it has limited value because of the relatively small sample size (only one fourth of the cores were analyzed for species composition).

The Upper System

Annelids dominated infauna in the oligohaline delta marshes of the upper system in Trinity Bay. The main worms were Laeonerieis culveri and several species of oligochaetes. Peracarid crustaceans, abundant elsewhere, were nearly absent at the delta. Among mollusks, Rangia cuneata and R. flexuosa were abundant in subtidal habitats adjacent to delta marshes.

The Middle System

In mesohaline marshes of Moses Lake and Smith Point, on the margin of Galveston Bay proper, infauna attained their highest densities and greatest variability. Dominant annelids were Streblospio benedicti, oligochaete spp., Capitella capitata, Polydora ligni and Hobsonia florida. Peracarids were mainly Hargeria rapax, Corophium sp., Ampelisca abdita, Grandidierella bonneroides and Gammarus mucronatus. Abundant mollusks were Amygdalum papyrium, Tellina sp., Odostomia sp. and Crassostrea virginica.

The Lower System

Infaunal densities in polyhaline marshes of West Bay and Christmas Bay were intermediate to those of the upper and middle system. Annelid and peracarid species were similar to those of the mid-bay. Annelids were dominated by Streblospio benedicti, Capitella capitata and oligochaete spp. Peracarids were dominated by Hargeria rapax, Ampelisca abdita and Grandidierella bonnieroides. The most abundant mollusks were Acteocina canaliculata, an unidentified gastropod species and Mulinia lateralis.

The dominant infauna in marshes of the Galveston Estuary have affinities to infauna of temperate marshes of the southeastern Atlantic. Hargeria, Streblospio, Capitella, oligochaetes and insect larvae were listed as dominants of salt marshes studied in Georgia (Knieb 1984) and North Carolina (Rader 1984). Wiegert and Freeman (1990) also refer to the abundance of terrestrial arthropods in Atlantic coast salt marshes. Insect larvae were common in Galveston Estuary marshes.

SUMMARY AND RECOMMENDATIONS FOR MONITORING

Marsh infauna in the Galveston Estuary are comprised of species expected in temperate estuarine systems. Dominant species are annelids and peracarids that are commonly abundant in other systems. Local composition is strongly influenced by salinity regime.

A survey in 1987 showed that marsh infauna increased in diversity from oligohaline to polyhaline (upper to lower) parts of the system. Abundances and species varied between the major taxonomic groups depending upon the area of the bay. Annelids were least diverse but most numerous in the upper bay. Peracarids were highest in abundance and diversity in the middle bay. Mollusks were most diverse in the lower bay.

Annual data on marsh infauna were only available from one site (the State Park marsh on Galveston Island in the lower system). Seasonal change is the strongest signal in these data and there are no evident annual trends. The detection of annual trends is severely restricted by the low number of years covered (only 4 years are available) and incomplete processing of the monthly data sets.

At a minimum, all of the remaining samples from the four year period at the State Park need to be processed. This would establish at least one competent baseline for the lower bay against which future sampling efforts could be compared.

Optimally, marsh sites also need to be established in other parts of the estuary with contrasting salinity regimes (upper and middle areas) for developing additional multi-year baseline data sets. The Trinity delta and Smith Point areas have existing marsh infauna data and may be good candidates for such monitoring.

Monitoring of marsh annelids and peracarids is important because of their role as forage for juveniles of other species. Many worms, amphipods and tanaeids thrive on the microalgae and plant detritus in marshes. The abundance and availability of these prey are vital to the productivity of secondary consumers, and especially to the juveniles of fishery species. Because marshes simultaneously provide abundant food and cover, and alternate habitats such as mangroves, algae beds and seagrasses are virtually absent from the Galveston Estuary, marshes are the principal nurseries. The species composition and abundances of infaunal in these marshes is a key component of the system.

The monitoring of marshes and their infauna needs to be established as a long-term program for the Galveston Estuary.

REFERENCES

- Baxter, K. N., and W. C. Renfro. 1967. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. U. S. Fish and Wildlife Service Fisheries Bulletin 66:149-158.
- Bell, S. S., and B. C. Coull. 1978. Field evidence that shrimp predation regulates meiofauna. *Oecologia* 35:141-148.
- Boesch, D. F., and R. E. Turner. 1984. Dependence of fishery species on salt marshes: the role of food and refuge. *Estuaries* 7:460-468.
- Childers, D. L., J. W. Day, Jr. and R. A. Muller. 1990. Relating climatological forcing to coastal water levels in Louisiana estuaries and the potential importance of El Nino-Southern Oscillation events. *Climate Research* 1:31-42.
- Flint, R. W., and J. K. Younk. 1983. Estuarine benthos: long-term community structure variations, Corpus Christi Bay, Texas. *Estuaries* 6:126-141.
- Hettler, W. F., Jr. 1989. Neuston use of regularly-flooded saltmarsh cordgrass habitat in North Carolina. U.S. Marine Ecology Progress Series 56:111-118.
- Kneib, R. T. 1982. Habitat preference, predation, and the intertidal distribution of gammaridean amphipods in a North Carolina salt marsh. *Journal of Experimental Marine Biology and Ecology* 59:219-230.
- Kneib, R. T. 1984. Patterns of invertebrate distribution and abundance in the salt marsh: causes and questions. *Estuaries* 7:392-412.
- McIvor, C. C., and W. E. Odum. 1986. The flume net: a quantitative method for sampling fishes and macrocrustaceans on tidal marsh surfaces. *Estuaries* 9:21-224.
- Mense, D. J., and E. L. Wenner. 1989. Distribution and abundance of early life history stages of the blue crab, Callinectes sapidus, in tidal marsh creeks near Charleston, South Carolina. *Estuaries* 12:157-168.
- Minello, T. J., and R. J. Zimmerman. 1983. Fish predation on juvenile brown shrimp, Penaeus aztecus Ives: the effect of simulated Spartina structure on predation rates. *Journal of Experimental Marine Biology and Ecology* 72:211-231.
- Minello, R. J., and R. J. Zimmerman (in press). The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp. In Dougherty, W.J. and M.A. Davidson, editors. *Frontiers of shrimp research*. Elsevier Science Publishers.

- Minello, R. J. and R. J. Zimmerman. 1991. The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp. 16 pages in Dougherty, W.J. and M.A. Davidson, editors. *Frontiers of shrimp research*. Elsevier Science Publishers B. V., Amsterdam.
- Morris, J. T., B. Kjerfve and J. M. Dean. 1990. Dependence of estuarine productivity on anomalies in mean sea level. *Limnology and Oceanography* 35:926-930.
- Rader, D. N. 1984. Salt-marsh benthic invertebrates: small-scale patterns of distribution and abundance. *Estuaries* 7:413-420.
- Rozas, L. P., and W. E. Odum. 1987. Use of tidal freshwater marshes by fishes and macrocrustaceans along a marsh stream-order gradient. *Estuaries* 10:36-43.
- Sikora, W. B., and F. H. Sklar. 1987. Chapter 6: Benthos. Pages 58-79 in Conner, W. H., editor. *The ecology of Barataria Basin, Louisiana: an estuarine profile*. U. S. Fish and Wildlife Service Biological Report 85(7.13).
- Stout, J. P. 1984. The ecology of irregularly flooded marshes of the northeastern Gulf of Mexico: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7.1).
- Thomas, J. D. 1976. A survey of gammarid amphipods of the Barataria Bay, Louisiana region. *Contributions in Marine Science* 20:87-100.
- Thomas, J. L. 1989. A comparative evaluation of Halodule wrightii Aschers, Spartina alterniflora Loisel and bare sand as nursery habitats for juvenile Callinectes sapidus. Master's Thesis. Texas A&M University, College Station, Texas.
- Thomas, J. T., R. J. Zimmerman and T. J. Minello. 1990. Abundance patterns of juvenile blue crabs (Callinectes sapidus) in nursery habitats of two Texas bays. *Bulletin of Marine Science* 46(1):115-125.
- Turner, R. E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. *Transactions American Fisheries Society* 106:411-416.
- Turner, R. E. 1991. Tide gauge records, water level rise, and subsidence in the northern Gulf of Mexico. *Estuaries* 14:139-147.
- Wiegert, R. G., and B. J. Freeman. 1990. Tidal salt marshes of the southeast Atlantic coast: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7.29).
- Weinstein, M. P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *Fisheries Bulletin* 77:339-357.
- Zimmerman, R. J., and T. J. Minello. 1984a. Densities of Penaeus aztecus, Penaeus setiferus, and other natant macrofauna in a Texas salt marsh. *Estuaries* 7:421-433.